ECONOMICS IN ACTION: THREE ESSAYS

BY

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DISSERTATION

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ABSTRACT

In this thesis, I examine the health, welfare, and distributional implications of the society's institutions and public policies in three separate chapters. In the first chapter, I show that exposure to Muslim religious fasting month during gestation results in significant decline in the body height. In the second chapter, I examine the welfare, fiscal, and environmental consequences of a structural change in the public policy that substitute indirect energy and food subsidies – price subsidies – with direct cash transfers to household. Finally, in the third chapter, I measure the distributional effects of several countrywide welfare programs in interaction with economic growth and households' characteristics. In the followings, I have provided summaries of each chapter.

In the first chapter, to estimate the effect of nutritional disorder during pregnancy on children's height, I use Demographic and Health Survey data from numerous developing countries that include children's exact birth dates and employ exposure to the Islamic fasting month of Ramadan as a natural experiment. I find that Ramadan-induced prenatal nutritional disorder causes a 3.5 to 10.5 millimeter decrease in the height of Muslim boys at ages 3 and 4. I identify no effect on females including children and children's mothers. I also show that exposure to Ramadan becomes significant when it occurs for more than 10 days, there is no intergenerational transmission from mothers to children, and latitude does not influence the effect. The robustness tests show that the results are not driven by selection into fertility, seasonality, or observations from a specific country.

In the second paper, I use the 1987-2010 Household Budget Surveys from the Statistical Center of Iran consisting of 273,879 observations, coupled with the price data from the Central Bank of Iran, to estimate the structure of demand for goods and services in urban areas of Iran. The estimation procedure assumes a Quadratic Almost Ideal Demand System (QUAIDS)

introduced by Banks et al. (1997). It uses the estimated demand system to study the implications of the removal of the massive subsidies on energy and basic foodstuff that were in place in Iran up to 2010. I examine the economy's consumption patterns, income distribution, private and social welfare, and the environment.

The third chapter employs quantile regression method and household expenditure surveys to assess the general equilibrium effects of public spending and social protection programs on household expenditure distribution in Iran. The approach captures the broad consequences of programs, taking into account their direct and indirect effects through price changes, interpersonal transfers, demonstration effects, and the like. I also control for and assess the role of household characteristics and geographic and time fixed effects. The case of Iran is interesting and important because in recent decades the country has experimented with new institutional arrangements to address poverty and has been relatively successful in this regard, as the findings confirm. This study covers the 1993-2006 period. For policy analysis I focus on 1998-2005, the so-called reform period in Iran. I find that growth has been unequalizing, but changes in education, government spending, and a unique agency established after the revolution of 1979 to provide social safety net have counteracted with that effect and raised the incomes of the bottom half of the population faster than the rest. The upper end of the distribution has also benefited somewhat, leaving those in the 50 to 85 percentiles behind.

To Azi for her love and support

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CHAPTER 1

THE EFFECT OF NUTRITIONAL DISORDER DURING PREGNANCY ON HEIGHT: RAMADAN AS A NATURAL EXPERIMENT

1.1 Introduction

Height is the most revealing indicator of nutrition at early life, and predicts morbidity and mortality in adulthood (Waaler 1984, Fogel 1994).[1] It is, thus, not surprising that height predicts economic outcomes such as occupation, wage, and income (Case and Paxton 2006, Mankiw and Weinzierl 2010). This is why economic historians use height as a marker of society's health and standard of living (Strauss and Thomas 1998, Steckel 2004). A large body of literature is devoted to evaluating the effect of malnutrition in childhood and birth year on height (Duflo 2000, Bozzoli *et al.* 2007, Banerjee *et al.* 2007, Bundervoet *et al.* 2009, Akresh *et al.* 2011, Akresh *et al.* 2012). However, studies that focus on the fetal life and examine the effect of fetal malnutrition on height are rare and often involve sizable measurement errors (Brainerd and Menon 2012, Rosales 2013).[2]

In this study, I focus on the fetal life and explore how nutritional disorder in utero affects height by using the exact birth dates of children under 5 years and exploiting the calendric nature of the incidence of the nutritional disorder shocks stemming from exposure to the Muslim fasting month of Ramadan.[3] As such, I can account for the detailed timing of nutritional disorder in utero. My econometric identification strategy, then, employs variations in timing of

[1] In this study, I provide evidence that the reason for the strong correlations of the rates of morbidity and mortality in adulthood with height can be the fact that the critical windows of development of vital organs overlap with the critical windows of growth in height.

[2] The major source of measurement errors in height studies, including those that focus on the fetal life, is the lack of information on individuals' exact birth date. In this study, I show that it can lead to considerable overestimation or underestimation of results.

[3] Ramadan is a month during which Muslims past the age of duty - 9 lunar years for women and 15 lunar years for men - are obligated to fast, i.e. abstain from eating, drinking, smoking, and sexual activities during daylight hours.

exposure to Ramadan during gestation and religion to identify the height effect. I test the validity of the identification assumption that timing of exposure to Ramadan is not driven by observable characteristics of children and households and estimate difference-in-difference regressions. My large data set that includes 80 Demographic and Health Surveys (DHS) from 35 countries and covers 27 birth cohorts allows for isolating Ramadan effects from seasonal effects.[4,5]

A major contribution of this study is proposing height as a highly informative connection between fetal environment and adulthood and old age diseases. The literature that seeks for the developmental origins of affliction in adulthood commonly views birth weight as the premium sign of developmental modifications in response to malnutrition in utero and the main medium to chronic diseases in adulthood (Barker 1999). In this study, I argue that height is more informative than birth weight because a fetus's weight gain largely occurs during the last weeks of gestation, which are the least important episodes of gestation from developmental point of view. However, a fetus grows in height during the entirety of gestation and the critical windows of growth in height overlap with the critical windows of development of vital organs such as the heart, kidney, and brain.[6] In line with this argument, my estimations show that nutritional disorder during the critical windows of growth in height has, in fact, greater impact on children's height.

This work also contributes to the literature of height studies in several ways. First, by using children's exact birth dates and calendric nature of Ramadan, it draws clear lines between prenatal and postnatal nutritional disorder and avoids the pertinent measurement errors. It also differentiates

[4]These 35 countries all have a sizable Muslim population (i.e. more than 10% Muslim population according to the World Bank data) with DHS samples containing the required information (namely, children's exact day, month, and year of birth, exact day, month and year of height measurement, children's mothers' religion, children's mothers' height, and households' socioeconomic characteristics).

[5]Since Ramadan is a month in the lunar calendar, its occurrence changes according to the commonly used solar calendars, e.g. western Gregorian calendar and Iranian calendar, such that it comes earlier each year, by about 11 days. Because of the slow forward shift of Ramadan through common solar calendars, the full rotation of Ramadan takes about 32 years. As a result, it is necessary to have numerous birth years in order to detach seasonal effects from Ramadan effect on height. Having 27 birth years in the data set decreases this concern substantially. Additionally, this study runs specific tests and rules out the influence of seasonality.

[6]It is also noteworthy that there is only a weak relationship between birth weight and height (Scott *et al.* 1982, Martorell *et al.* 1994, Roseboom *et al.* 2000, Eriksson 2006).

between nutritional disorder during months of gestation. Subsequently, this work analyzes height effects by detailed timing of nutritional disorder according to the growth dynamic of a fetus. Second, by using exposure to Ramadan, this work employs a direct measure for fetal nutritional disorder, while commonly used measures, i.e. natural or human disasters, are indirect measures of fetal nutritional disorder. Therefore, this study estimates height effects that are less polluted with potential unobservable factors or the influence of other shocks. Third, in this work, a clear separation of the treatment and control groups of individuals, in terms of exposure to Ramadan environment, has become possible by using information on mothers' religion and children's exact birth date. However, it is difficult to define sharp boundaries across time and space for natural and human disasters.[7] Fourth, this work documents gender differences in carrying height effect of nutritional disorder in utero. Fifth, this work estimates age-specific height effects of nutritional disorder in utero in order to show the cumulative nature of height development.

This work substantially contributes to the literature of Ramadan studies as well.[8] First, this work extends Ramadan studies to a variety of developing countries, whereas existing Ramadan studies rely on limited data.[9] Therefore, this work presents a more accurate picture of the effect of Ramadan on health.[10] Second, this work investigates aspects of Ramadan that have not been studied yet. Most important, this is the first study that demonstrates the effects of exposure to Ramadan on height. In addition, it investigates how a change in the intensity of exposure alters the effects, how the effects can be transmitted from mothers to children, and how dispersion across latitudes

[7]My data does not tell if a mother fasted during pregnancy, but I can determine when her pregnancy collided with Ramadan. Thus, I can certainly tell if she was exposed to a fasting environment during pregnancy.

[8]This work is not the first to use Ramadan as a means of shedding light on the relationship between prenatal nutritional disorder and postnatal outcomes. Existing Ramadan literature shows the evidence of an association of exposure to Ramadan in utero with low birth weight, negative educational performance, unfortunate labor market outcomes, and predisposition to old age disabilities (Almond and Mazumder 2011, van Ewijk 2011, Almond *et al.* 2012, Majid 2012).

[9]Ramadan studies acquire data either from Muslims living in the U.S. and U.K. or from Muslims in Indonesia, Uganda, and Iraq.

[10]In fact, the magnitude of similar effects can be considerably larger in the context of developing countries. For example, while Almond and Mazumder (2011) measure an average of 40 grams decrease in birth weight of the exposed newborn Muslims in Michigan, Majid (2012)'s measurement of the same effect in Indonesia amounts to 270 grams.

changes the severity of the effects.

I identify the first signs of the height effects of Ramadan-induced nutritional disorder in utero at age 2. The effects become stronger and more significant thereafter. To be more specific, I find that a full 30-day exposure to Ramadan during gestation regardless of its timing leads to an average 4mm-5.5mm decline in the height of 3 and 4 year-old Muslim boys when compared to the non-exposed Muslim boys and non-Muslim boys. If the height effect is decomposed to months of gestation, the peaks of the effects coincide with the crucial windows of fetal development in length. The largest effects are traced to months 3 and 4, when pre-bone cartilage models and the primary ossification centers form, and months 5 to 7, when bone cells develop at their highest rates. For example, if Ramadan exactly coincides with any of the crucial months in utero, then the subsequent height decline amounts to 7.5mm-10.5mm for a 4 year-old Muslim boy. The height effects of exposure to Ramadan in utero are found in male and not female children. I also find no effect on the height of the children's mothers. In addition, I find no sign of intergenerational transfer of Ramadan-induced height decline from mothers to children in accordance with the finding that female children and mothers bear no height effect from exposure to Ramadan.

In addition, I find that the height effects appears after 10 days of exposure, but the size of the marginal effects decline afterwards. Also, no significant impact of latitude on the results is detected. These two pieces of evidence suggest that Ramadan effects are probably not driven by intense fasting of pregnant women. Although some Muslim women may fast in part during pregnancy, the fasting environment during Ramadan in Muslim communities, which provokes dietary and sleep disorders, is probably the main driving force of the effects.

This study has enormous policy implications. I study the decisions that people make to basically be malnourished or collectively create an environment that generates persistent dietary disorder for pregnant women. I show that these conditions can have long-term negative health impacts for a fetus. These conditions, which can be recreated by persistent mill-skipping, neglecting minor chronic diseases, getting into weight-loss plans, or taking diet pills during pregnancy, can be changed since they are originated from people's decisions. Thus, from policy-making point of view, this study highlights the importance of providing information to the public about the specific risks of maternal dietary disorder during pregnancy. Therefore, this study is different than the other works that look at disasters, such as wars, famines, or epidemics that are essentially unpredictable or out of human's control.

The rest of this study is organized as follows. In Section 1.2, the related biological and economic background is presented. In Section 1.3, the data and econometric models are introduced. In Section 1.4, the main results are presented. How children's height is influenced by nutritional disorder in utero and how the sexes are different in bearing the effect are conferred in this section. In Section 1.5, further investigations about the Ramadan effect, such as intensity, intergenerational transmission, latitude, and reversibility are discussed. Section 1.6 concludes.

1.2 Background

1.2.1 Height as an indicator of health, well-being, and success

There is a well-established inverse relationship between height and morbidity and mortality rates, observed by Waaler (1984) and its further interactions (Barker *et al.* 1990, Fogel *et al.* 1993, Smith *et al.* 2000, Jousilahti *et al.* 2000, Song *et al.* 2003, Carslake *et al.* 2013). Economic historians consider height to be the best examiner of prosperity and economic development (Steckel 1995, 2004).[11] Height is also a known predictor of individual level productivity and success (Fogel 1987).

The literature that connects height to labor market status dates back to Gowin (1919). Case and Paxton (2006) show that the positive correlation between height and income still holds in the U.S. and the U.K. such that a one-inch increase in the height of American and British men is associated with a 2.4% and 1.5% increase in their earnings, respectively.[12] The connection between height and labor market outcomes has been reported in developing countries as well (Haddad and Bouis 1991, Strauss and Thomas 1998).[13] In

[11] Economic historians rely on size distributions of calories to explain secular trends in malnutrition, morbidity, mortality, and economic growth (Fogel 1994, Fogel and Floud 1994).

[12] For the U.S., they use data from 1986 to 1994. For the U.K., data of the 1970s cohort is used.

[13] Several hypotheses are proposed and tested to explain the relationship. Humphreys

a more recent study Mankiw and Weinzierl (2010) uphold the correlation of height and wage in the U.S. and suggest an income tax credit for taxpayers who are short in height.[14]

1.2.2 Determinants of height

Heredity accounts for about 80% of the determining factors for height (Silventoinen 2003). Nevertheless, the differences across groups and populations are predominantly attributable to environmental elements. Hence, genetic differences cancel out in intra-population and most cross-population comparisons (Steckel 1995, Beard and Blaser 2002).[15] Environmental determinants of height, i.e. nutrition and diseases, are most influential at the early ages of life. The significant role of net nutritional intake during infancy and childhood in shaping height is extensively documented in biologists and economists (Duflo 2000, Hoddinott and Kinsey 2001, Crimmins and Finch 2006, and Bozzoli *et al.* 2007, Bundervoet *et al.* 2009).[16]

It is possible that the fetal environment also has a role in determining a person's height. Recently, studies of the long-term effects of shocks to the fetal environment are framed under the *fetal origins hypothesis*.[17] According to this hypothesis, if the fetus encounters difficult conditions, then it

et al. (1985), Abbott *et al.* (1998), and Case and Paxton (2006) connect height to cognitive abilities. Blane *et al.* (1999) and Bielicki and Szklarska (2000) explain it by social mobility. And, Freedman (1979) and Young and French (1996) use self-esteem induced by height to explain it.

[14] In a follow-up study, I document the effect of Ramadan nutritional shocks during gestation on adults' income and working hours in Nigeria and show that height can serve as a physiological medium of the fetal shocks to adulthood (Caruso and Karimi 2014).

[15] Whereas genetics are a critical determinant of height, different nations' secular height increases since the mid nineteenth-century occurred so rapidly that they cannot be attributed to long-run natural selective factors (Floud *et al.* 1990, Beard and Blaser 2002). Floud *et al.* (1990) illustrate that the average height at conscription age in Denmark, Netherlands, Norway, and Sweden has increased by more than 10cm from the 1860s to 1980s (page 25). They document a similar trend in Britain by extending it to the 1740s (page 289). The elevation of height is particularly striking in the Netherlands, which was counted among the European countries with the shortest people in the nineteenth-century, from about 165cm to 180cm. Beard and Blaser (2002) present recent data from 11 European countries and show 3cm to 6cm increases in the average height at the same age, from the years 1960 to 1990.

[16] The correlation between height at adulthood and at age 2 is about 80% (Schmidt *et al.* 1995).

[17] Sustained interest in the fetal environment, from early supportive studies (Ebbs *et al.* 1941, Burke *et al.* 1943), to the discouraging *perfect parasite hypothesis* (Darby *et al.* 1953, Thomson 1958, 1959), sparked to renewed attention from Barker *et al.* (1990).

strategically adapts its development to increase its chance of survival both in utero and after birth. In other words, the fetus expects a challenging postnatal life and conducts *predictive adaptive responses* (Gluckman and Hanson 2005). The survival-oriented modifications, however, might negatively affect some organs. For example, the likelihood of suffering from heart disease, diabetes, and obesity in adulthood is higher for starved fetuses (Barker 1998a, 1998b). Depending on the timing of in utero shocks, the adaptive responses will be different and their postnatal health consequences vary accordingly, highlighting the evolutionary concept of *critical windows of development.*

There is a broad range of literature that addresses the effects of malnutrition in utero on adults' diseases using different types of shocks.[18] Height has also been subjected to similar analyses.[19] Banerjee *et al.* (2007) use the regional variations in the timing of 1863-1890 pest attacks to French vineyards to identify the long-term height effects of the resultant income shocks. They find that an affected 20 year-old man is about 6mm to 10mm shorter than an unaffected man. Cutler *et al.* (2007) use America's Dust Bowl and find no significant height effect caused by the income shocks. Maccini and Yang (2009) use district level and seasonal variations in rainfalls in rural Indonesia to measure the effect of weather shocks at early life on height, among other outcomes. They find that 20% more rainfall at the year and location of birth is associated with 5.7mm height increase in women. Meng and Qian (2009) employ variations in the regional intensity of China's 1959-1961 famine at early life and find that birth during the famine is associated with a 27mm decrease in adults' height. Dercon and Porter (2010) use the 1984 Ethiopian famine to find that children who were exposed to the peak of the famine are shorter than the non-exposed children by 30mm. Akresh *et al.* (2011) use crop failures and civil wars in Rwanda at 1980s and 1990s to show that

[18] A long list of medical problems are examined using the 1944-1945 Dutch famine (Neugebauer *et al.* 1999, Roseboom *et al.* 2000, Painter *et al.* 2005, Roseboom *et al.* 2006, Heijmans *et al.* 2008), influenza epidemic of 1918 (Almond and Mazumder 2005, Almond 2006), Chernobyl radioactive fallout (Almond *et al.* 2007), the siege of Leningrad (Stanner *et al.* 1997), income shocks (Cutler *et al.* 2007), and religious customs (Almond and Mazumder 2011, van Ewijk 2011).

[19] The early studies of the effect of in utero shocks on height are simple tabulations or graphs that compare mean height of the exposed and the non-exposed individuals to the shocks (Volaoras 1970, Zena *et al.* 1975, Susser and Stein 1994 , Stanner *et al.* 1997). However, on account of increased data availability in recent years, a growing body of literature analyses the height effects of in utero malnutrition using detailed background information and meticulous identification strategies.

birth during crop failures is associated with significant height decreases for women. Birth during the civil wars results in height decrease for both men and women. These studies, however, do not distinguish between prenatal and postnatal periods since they compare the height of individuals who were born in shock areas to that of individuals in comparison groups.

There are few recent studies that attempt to distinguish between prenatal and postnatal shocks. Akresh *et al.* (2012) examine the effects of exposure to 1967-1970 Nigerian civil war in utero, at ages 0-3, at ages 4-6, at ages 7-12, and at ages 13-16 on women's height. They find no effect of in utero exposure to the civil war, but exposure at early childhood is associated with a 7.5mm decrease in height. Brainerd and Menon (2012) use variations in the concentrations of agrichemical fertilizers by season and area in rural India and document the negative effect of exposure to contaminated water in the month of conception on children's height. Rosales (2013) uses data from Ecuador and examines the height effect of exposure to 1997-1998 El Nino floods during gestation and finds that one additional month of exposure to the floods decreased the height-for-age of 5 to 7 year-old children by 0.03 standard deviations. The effect is significant only for the third trimester of gestation.

The studies that are mainly focused on in utero environment suffer from several problems. First, they contain a measurement error originated from a lack of information about individuals' exact birth date. Since only year and month of birth are available to the authors of the papers, they cannot draw clear lines between the preconception month and the first month of gestation, between trimesters of gestation, or between the last month of gestation and the first month after birth. Thus, such studies cannot analyze the effect of exposure by months of gestation. As such, they cannot offer a detailed examination of the effect of malnutrition in utero based on the timing of fetal growth. Second, such studies do not employ "direct" measures of early life malnutrition and assume it is induced indirectly by the shocks, i.e. civil war, chemicals, and floods. Notably, the involvement of unobservable factors can potentially distort the connection between the shocks and nutritional insufficiency.[20] Third, the the studies often contain a measurement error

[20] For example, access to a network of relatives, friends, or tribe members that can provide support for some affected households but not others is usually an unobservable factor.

stemming from the fact that a sharp definition of the boundaries of the shocks across time and space is difficult. Fourth, they do not study gender differences in the carrying height effect of malnutrition in utero.

1.2.3 Ramadan as a natural experiment

If the Islamic fasting month of Ramadan is utilized as a natural experiment, then there will be less concern about the connection between in utero shock and actual in utero malnutrition.[21] In addition, if exact birth dates are available, then the calendric nature of incidence of Ramadan allows for determining the exact timing of exposure to Ramadan in utero as long as it does not affect normal gestation length. Plus, boundaries of the influence of Ramadan can be defined sharply across individuals and time given the information of the mother's religion and the child's exact birth date.[22]

The newly-developed Ramadan literature uses Ramadan's unique characteristics to identify adverse effect of malnutrition in utero on birth weight, vulnerability to chronic diseases and disabilities at old age, wage at adulthood, and education (Almond and Mazumder 2011, van Ewijk 2011, Almond *et al.* 2012, Majid 2012). Almond and Mazumder (2011) and Majid (2012) show that in utero exposure to Ramadan causes low birth weight. The studies link the effect of Ramadan to later stages of life in accordance with an empirical stream of studies that support the fetal origins hypothesis. While height provides a better proxy for fetal nutritional environment in comparison to birth weight, for example, it has not been used to link the effect of gestational malnutrition to adulthood by the Ramadan studies.[23]

[21]In Section 5, I show that Ramadan nutritional shock is in the form of nutritional disorder than malnutrition. Thus, I am intended to use the phrase "nutritional disorder" to describe Ramadan nutritional shock in this study.

[22]The only non-Ramadan in utero shock that provides sharp and clear boundaries of treatment in space and time is the Dutch famine, but it has only been used for preliminary height studies.

[23]van Ewijk (2009) estimates the height effect of exposure to Ramadan in utero along with an array of other health outcomes. Despite the prediction of medical theory, he finds almost no effect of exposure to Ramadan in utero on Muslims' anthropometric characteristics. For example, exposure to Ramadan only at the month of conception has weakly significant negative effects on Muslim women's height. Therefore, in the published version of his study, van Ewijk (2011) drops height analyses. van Ewijk (2009)'s height analysis would improve with sufficient number of observations. He has less than 7,400 height observations for men at all ages and almost the same number for women, while it is essential to conduct height analyses by age, especially for individuals under age 21.

The Ramadan studies have found no evidence that parents set the time of conception according to the occurrence of Ramadan. The relationship between exposure to and observance of Ramadan is another concern. Observance of Ramadan is expected to be high during the first month of pregnancy when it is more likely that pregnancy is not realized. When realized, pregnant women are generally exempted from fasting, but they are required to make up for it after parturition. Nevertheless, some mothers choose to fast in order not to evade the religious task or not to do it alone later.[24] Regardless, those women who do not fast face dietary restrictions and disorders. Restaurants and food shops are usually closed at daytime during Ramadan in most Islamic countries. At home, pregnant Muslim women usually set the times of their main meals to before sunrise and after sunset when the fasting members of households eat. Subsequently, their dietary disorders are accompanied by a derangement of their sleeping times. Thus, pregnant Muslim women observe Ramadan either by fasting or by experiencing diet disorders.

1.2.4 Height and birth weight

In this section, I explain the relationship between height and birth weight and emphasize on the importance of measuring height effect in conjunction with the documented birth weight effect of malnutrition in utero. The strong correlation of severe low birth weight and shortness in height is indisputable, as the same correlation exists between that and an array of long-term health problems (Ericson and Kallen 1998, Hack *et al.* 2003). Aside from extreme cases, birth weight has little effect on a child's growth and does not determine height (Scott *et al.* 1982, Martorell *et al.* 1994, Strauss 1997). In this regard, Kusin *et al.* (1992)'s findings are particularly illustrative. In a randomized experiment, they gave low and high caloric supplements to pregnant women at the third trimester and recorded children's weight and height until the age of 5. They find that height differences in the children of the two groups tended to increase and become statistically significant while weight differences tended to decrease and become statistically insignificant with age.

[24] The sparse evidence on the observance of Ramadan shows that majority of pregnant Muslim women observe Ramadan for one day at least. As it is documented by Almond and Mazumder (2011), between 70% to 90% of surveyed pregnant Muslim women in Gambia, Iran, Singapore, U.K., U.S.A., and Yemen had observed Ramadan for one day at least.

To explain the different trends in height and weight gain after birth, one should consider that weight is a short-term indicator of health that mainly reflects the nutritional environment around the time of measurement. As such, birth weight mainly reflects the nutritional status at the latest weeks of gestation. Thus, it is more possible that a deficiency in birth weight can be overcome shortly after birth. Height, however, is a long-term accumulative indicator of health. In other words, it is less likely that defects in height at critical windows of growth can be compensated.

Looking into the dynamics of fetal growth displays the forces behind the different trends. As it will be explained in details in the next section, the potential for growth in height, which is laid in development of long bones, starts forming from the end of the first month of gestation and a fetus grows in length in a steady, almost linear, rate until birth. A fetus's weight gain, however, follows an exponential pattern such that the rate of gaining weight increasingly goes up when approaching to birth.[25] That is, the later weeks of gestation are more important in terms of fetus's growth in weight. Hence, it is more likely that weight deviation of the newborn, from the typical weight, is caused by a nutritional deficiency during the latest weeks or month of gestation.[26]

The fetal origins hypothesis also predicts that fetal programming may not necessarily affect birth size (Eriksson 2006). In fact, any inflicted change in phenotype need not be promptly visible at birth. For example, Roseboom *et al.* (2001)'s findings from the Dutch famine show that the fetal programming of an adulthood disease can occur with no trace on birth size. Therefore, biological research about the link between birth weight and height is in no way conclusive. Therefore, height requires independent attention. In the next section, I argue that height may be even more informative that birth weight when fetal programming is traced because critical windows of fetal growth in height overlap with critical windows of development of vital organs in utero.

[25] This increasing rate of weight gain is mainly due to accumulation of fat and enlargement of the fetus's organs, which have undergone the crucial stages of completion during the first half of pregnancy in most cases. Visit the following link to see a graph of a fetus's weight gain during gestation: `http://www.babycenter.com/average-fetal-length-weight-chart`

[26] Moore and Persaud (2008) show that poor nutrition defects a fetus's weight from its normal pattern from about the mid-eighth month of gestation (Figure 6-13, Page 103).

1.2.5 Biology of fetal development in length

In this section, first I give a brief overview of the biological process of fetal development as it enhances the capacities of growing in height. Height is mainly determined by the length of long bones, thus I give a cellular description of development of long bones and highlight the timing of the pertinent stages, or the critical windows. Then, I compare the timing of the critical windows of development in height with the timings of the critical windows of development of human body's vital organs to suggest that height is a more informative indicator of health than birth weight. The contents of this section will also afford a guideline to interpret the empirical results.

Long bones develop in four distinctive stages during the gestational period. The sequence of the stages is mesodermal condensation, chondrification, formation of primary ossification centers, and early endochondral ossification.[27] During the fourth week of gestation, by migration of embryonic stem cells to areas destined to grow bones and the rapid differentiation of the stem cells, limb buds appear. During the next two weeks, column-like mesodermal condensations appear along the axis of the limb buds. The next stage is chondrification, i.e. development of cartilage models of the limb bones within the mesodermal condensations, that starts from week 6 and continues to week 18 of gestation (Figure 1.1, Illustration 1-4).[28] The cartilage models are the templates of the final bones and emulate their future size, shape, and position. During the development of each template, an extra cellular matrix containing vascular growth factors develops as well (Larsen 1997, Cooper *et al.* 2006).

While cartilage models are growing in size, a parallel process is underway leading to formation of the primary ossification centers, which takes place during the second and third months of gestation (Figure 1.1, Illustration 2-4).[29] Early endochondral ossification, i.e. materialization process of the long

[27] In general, fetal skeleton development involves two distinct processes: the ossification of flat bones, such as skull and facial bones, and the ossification of long bones, such as found in legs and arms. These are distinguished by the presence or absence of cartilage (Khurana 2009).

[28] The timing of the start of chondrification is different for different bones.

[29] Primary ossification center is the first site where a long bone begins to take shape. The process that leads to formation of a primary ossification center includes the following stages: (i) formation of a bony collar around the cartilage model; (ii) partial calcification of the cartilage matrix and creation of a cavity in its mid-region; (iii) invasion of blood vessels into the cavity; (iv) migration of stem cells into the cavity, differentiation of the

bones, starts after the sufficient expansion of cartilage models and formation of primary ossification centers. Endochondral ossification is, in fact, the expansion of the primary ossification centers at the presence of the remaining cartilage at both ends of the cavity in the middle region of bones (Figure 1.1, Illustration 5-6). For some bones, such as ischium and calcaneous, this stage starts from mid fourth month of gestation and persists until birth. But for long bones of arms and legs, endochondral ossification starts from the fifth month of gestation (Larsen 1997, Rose and Pawlina 2010).[30]

The time lines of the four stages of development of the limbs during gestation, which I call them as the critical windows of development of the limbs in utero, are shown in Figure 1.2. Focusing on long bones, two phases of development can be distinguished: pre-ossification phase that includes the first three stages of development (around the end of the first month to around the end of fourth month) and ossification phase that includes that last stage (from about the beginning of the fifth month to birth).

The development processes of both phases are influenced by the mother's nutrition (Gluckman *et al.* 1996, Cooper *et al.* 2006). Also, as cartilage models lay the framework for early endochondral ossification, the two phases are interdependent.[31] There is evidence that calcium and vitamin D, transferred from the mother to the fetus via the placenta, are crucial for the process of ossification. The transfer commences around week 20 of gestation (Cooper *et al.* 2006).[32]

Figure 1.2 also shows the critical windows of development of human body's vital organs and systems during gestation. Almost all of them have an evolutionary phase during which the organ's components shape and complete and an expansionary phase during which the completed organ enlarges alongside the growth of fetus.[33] For the heart, the evolutionary phase consists of the

stem cells alongside an expansion of blood vessels.

[30]Subsequent, stages of ossification, including the formation and expansion of the secondary ossification centers, take place after birth (Figure 1.1, Illustration 7-10).

[31]The interdependency is also justified by the fact that the expansion of primary ossification centers is supported by the presence of cartilage at its ends; this is called *epiphyseal cartilage* (Rose and Pawlina 2010).

[32]Less is known about the effects of maternal nutrition and growth of cartilage models in the first trimester. However, from animal studies, there is an abundance of evidence of the effect of fetal undernourishment on bone growth, skeleton growth, and bone related diseases. Lanham *et al.* (2011) provide the most recent and extensive survey of such studies.

[33]This rule does not apply to the respiratory system. Since, the respiratory system

episodes indicated by *H1*, *H2*, and *H3*, which span from week 3 to week 12 of gestation, and the expansionary phase consists of the episode indicated by *H4*, which spans from the second trimester of gestation to birth. For the digestive system, the time spans of the two phases are the same as those for heart. That is, the evolutionary phase consists of the episodes indicated by *D1*, *D2*, *D3*, *D4*, and *D5*, which span from week 3 to week 12 of gestation, and the expansionary phase consists of the episode indicated by *D6*, which spans from the second trimester of gestation to birth. For the kidney and the brain, the evolutionary phase lasts for a month more.

The idea of dividing development of organs to evolutionary and expansionary phases can also be applied to the development of long bones such that the pre-ossification and ossification phases resemble evolutionary and expansionary phases, respectively. As it can be seen in Figure 1.2, the time spans of the two phases of development of long bones approximately coincide with the time spans of the two phases of development of the heart, the digestive system, the kidney, and the brain. More specifically, the time line of the evolutionary phase of development of long bones encompasses the time lines of the evolutionary phases of the organs. The coincidence suggests that height may be more informative than birth weight if long-term health is considered. As it was described in section 2.4, the major weight gain of a fetus takes place during the last trimester of gestation in which the last weeks of gestation are of far more importance. These times coincide only with a part of one phase of development of vital organs, i.e. expansionary phase.

1.2.6 Selective male misery

In this section, I review evidence of a greater vulnerability of male fetuses to hardship in comparison to female fetuses. While a smaller number of female fetuses are conceived than males, a stream of clinical studies from the 1960s records physical, psychological, and neurological disadvantages of the males in comparison to the females. For example, Neonatal mortality and morbidity rates, susceptibility to many diseases, and learning and behavior disorders are higher for male. Also, the risks of abortion, premature birth, and stillbirth are significantly higher in male fetuses (Singer *et al.* 1968,

is not going to be used during gestation, but it evolves and completes during the entire gestation.

Gualtieri and Hicks 1985, Lavoie *et al.* 1998). Loke (1978) and Gualtieri and Hicks (1985) review the possible causes of the sex differences and conclude that female fetuses are capable of better adaptation in utero environment than male fetuses.[34] The accumulated evidence of sex differences in affliction has led to the *fragile male hypothesis* (Kraemer 2000).

Studies that provide causal evidence of the fragile male hypothesis are focused on the effect of in utero shocks on sex ratio using earthquakes, smogs, floods, wars, severe life events, and Ramadan (Fukuda *et al.* 1998, Lyster 1974, Zorn *et al* 2002, Hansen *et al* 1999, Almond and Mazumder 2011). However, evidence of the hypothesis from afterbirth incidences of disease is generally observational and focused on neurological problems. One unique feature of this study is that it allows for documenting sex differences in a non-neurological disorder, namely height, in childhood through a causal analysis.

1.3 Data and Econometrics Model

1.3.1 Data

I use Demographic and Health Survey data. The data provide information on fertility, family planning, maternal and child health, nutrition, malaria, and HIV/AIDS in about 90 developing countries. Initially, I take the samples of all of the countries that have at least a sizable minority of Muslim population. These include 102 DHS samples from 45 countries. Among them, I drop the samples lacking children's exact birth date, children's height information, or mother's religion. The exact birth dates are required to compute precise measures of exposure to Ramadan, and information indicating a mother's religion is required to distinguish Muslims from non-Muslims. Applying these criteria leaves 86 samples from 37 countries. After assigning consistent variable names and variable contents to the remaining samples, I append them and run several consistency tests. First, I inspect height measurement dates. I drop observations with a missing height measurement day because it is not

[34] Loke (1978) describes evidence of the differential viability in genetics, the number of previous male pregnancies, and blood groups. Gualtieri and Hicks (1985) discuss the role of maternal insufficiency, mainly rooted in genetics, in the higher vulnerability of male fetuses.

possible to generate height-for-age Z-scores for them. I also drop observations for which days of measurement and interview are not identical to avoid uncertainty about the causes of the difference.[35]

Second, I examine the reported height-for-age Z-scores, or height-for-age Z-scores. Since different reference populations are used to compute the Z-scores at different phases of DHS, height-for-age Z-scores of children of the same height and age, but in different samples, are not necessarily the same. To prevent this type of inconsistency, I recompute height-for-age Z-scores by utilizing a single reference population across all of the samples. In practice, I use Child Growth Standards, provided by the World Health Organization, in 2006 for children.[36] These child standards are gender-specific in days of age from birth to day 1856, i.e. the end of the fourth year of age. After computing uniform height-for-age Z-scores, I retain only the data of children with Z-scores in the range of -6 and 6.

While this study focuses on children's height by using children's height-for-age Z-scores, adults' Z-scores are also required to evaluate the effect of exposure to Ramadan in utero on children's mothers' height. To compute the uniform height-for-age Z-scores for adults, I use WHO Reference 2007 for years 5-19. The standards for years 5-19 are also age-specific but in months of age, from month 61 to 218.[37] For adults older than 19, I assume that height remains unchanged.[38]

Third, I drop data concerning children who have a mother with height that is either below 100 or beyond 200. I take this action to rule out mismeasurement, misreporting, or genetic anomalies. Finally, I drop observations with no information about parents' education and household wealth. Cleaning the pooled data for height measurement issues, extreme values of

[35]In the absence of days of measurement, my attempts to replace them with days of interview were unsuccessful. When the day of measurement is reported, it matches to the day of the interview in about 86% of cases. For the rest, the day of measurement is either before the day of interview (77% of the cases) or after the day of interview (23% of the cases). The reason for the later is unclear, but the former is possible if anthropometric measures are transferred from children's health cards. Thus, to avoid any unexplained measurement error, I only keep the observations for which the days of measurement and interview are the same.

[36]These standards that are internationally representative replace the formerly used NCHS standards. The WHO standards are also more precise, especially in early infancy. The standards are publicly available at http://www.who.int/nutgrowthdb/en/

[37]The adults' standards are publicly available at http://www.who.int/growthref/en/

[38]This is not a strong assumption because the growth in body height after the age of 19 is very slow (Beard and Blaser 2002, Figure 3A).

height-for-age Z-scores and mothers' height, and missing parental education and household wealth shrinks the number of samples and countries to 80 and 35, respectively. The total number of remaining observations is 251,370. In Table 1.1, the number of observations from each country in the pooled data set is presented by religion and gender. The numbers show that there are almost equal numbers of Muslims and non-Muslims and, also, boys and girls in the finalized data set.

1.3.2 Measures of exposure to Ramadan

I use the exact birth date of a child and go backward for about a year to find out if any pre-birth-day has collided with Ramadan. Ramadan is a month on the lunar calendar. Ramadan varies by years when considered according to the commonly used solar calendar. Thus, to find the collision of a pre-birth-day with Ramadan, I need to record occurrences of Ramadan from the mid-1980s to 2011, i.e. the time period for which births of the children in the dataset have taken place. Considering the collision of every pre-birth day with Ramadan, the timing of exposure can be computed assuming a given length for gestation. I have assumed typical 40-week gestation period for each child. Hence, the number of days of exposure in entirety, in trimesters of, and in months of gestation can be determined (Figure 1.3).[39]

Knowing whether any pre-birth-day of gestation is a Ramadan day allows for calculating the hours of fetal exposure to Ramadan. First, I determine the date of any pre-birth-day that has collided with Ramadan on the solar calendar. This allows me find the "yearly day numbers"of the collision days, which are numbers between 1 to 365 or 366.[40] Then, I use yearly day numbers of the collision days and latitude degrees of the place of residence, assuming

[39] Obstetricians use the last period of a pregnant woman's menstruation to estimate the fetus's age of gestation. Since fertilization can transpire only after ovulation and ovulation takes place halfway during the monthly menstrual cycle, it is estimated that the fetus is about 2 weeks old relative to the occurrence of the mother's last menstruation (Altman and Bayer 2001, p. 282). Almond and Mazumder (2011) use reported physician estimated lengths of pregnancies beside assumptions about the length of gestation and find no significant difference in the results. Physician estimated lengths of gestation are not reported for the children in the DHS data files. Therefore, I rely on an assumption about the length of gestation. While I assume 40 weeks is the duration of gestation for all children, changing it to one week or two weeks more and less does not alter the results.

[40] For example, if January 10 is a day of gestation colliding with Ramadan, then yearly day number of this collision day is 10.

that mothers' current place of residence is the same as their place of residence during pregnancy, to compute the numbers of daylight hours in every collision day.[41] Numbers of daylight hours indicate the length of exposure to Ramadan in a single day. Finally, once the hours of exposure at each pre-birth collision day are calculated, I compute the hours of exposure in entirety, in trimesters, and in months of gestation.

Forty weeks of gestations consist of 280 days. Since I chose to work with trimesters and months of gestation, I assume having 279 days of gestation that can be divided to 3 and 9 to obtain integer numbers for lengths of trimesters and months of gestation, respectively. Hence, trimesters and months last for 93 and 31 days, respectively, in my calculations. By dividing the gestation period as described above, I define the following variables:

HER279: hours of exposure to Ramadan during the entirety of gestation

$HERt_i$: hours of exposure to Ramadan during the i-th trimester of gestation, i=1,2,3

$HERm_i$: hours of exposure to Ramadan during the i-th month of gestation, i=0,1,...,9

DER279: number of days of exposure to Ramadan during the entirety of gestation

$DERt_i$: number of days of exposure to Ramadan during the i-th trimester of gestation, i=1,2,3

$DERm_i$: number of days of exposure to Ramadan during the i-th month of gestation, i=0,1,...,9

1.3.3 Identification strategy

To identify the effect of malnutrition in utero on height, I exploit variations in religion and in timing of exposure to Ramadan during gestation. In practice, I use a difference-in-difference strategy where I ask whether Muslim children who were exposed to Ramadan during gestation are shorter in height than Muslim children who were not exposed to Ramadan during gestation, relative to non-Muslim children. I ask the question for different measurements of

[41]In most of the DHS samples, the approximate latitude number of the place of residence is included in a separate data file, named Geographical Database. For the samples with no Geographical Database, I use the city or town of residence to find the corresponding latitude.

exposure to Ramadan and do so separately for boys and girls at different years of age. Therefore, my identification assumption is that the occurrence of Ramadan does not affect the timing of conception and pregnancy.

In Table 1.2 Panel A, I have presented the summary statistics of the observable characteristics of boys and girls categorized into Muslims and non-Muslims, which in turn are divided into four groups: those who are not exposed to Ramadan, those who are not fully exposed (1 to 29 days of exposure), and those who are fully exposed (30 days of exposure). Comparing the exposed and non-exposed Muslim boys and girls in terms of the characteristics shows no sign of selection bias in exposure to Ramadan.

The identification strategy is illustrated in Figure 1.4 where non-parametric relationships between height-for-age Z-scores and months of age are estimated for the exposed and non-exposed Muslim boys and girls.[42] Figure 1.4A shows that the difference between height-for-age Z-scores of the exposed and non-exposed Muslim boys is minimal during the first 24 or 25 months of life, but it starts to increase thereafter. More specifically, Muslim boys who are exposed to a full month of Ramadan during gestation (solid line) are consistently shorter in height than Muslim boys who are not exposed to Ramadan during gestation (dashed line) at ages 2, 3, and 4. Figure 1.4B, however, does not show a consistent pattern for the difference between height-for-age Z-scores of the exposed and non-exposed Muslim girls at the late childhood.

To further illustrate the identification strategy, I have provided the mean and standard deviation of height-for-age Z-scores of boys and girls who are not exposed to Ramadan, are fully exposed to Ramadan, and are partially exposed to Ramadan by years of age and religion in Table 1.2 Panel B. Comparing the mean height-for-age Z-score of Muslim boys who are not exposed to Ramadan with that of Muslim boys who are fully exposed to Ramadan reveals a developing negative effect by age. More specifically, the latter is less than the former by 0.07, 0.12, and 0.16 standard deviations at age 2, 3, and 4, respectively. For Muslim girls, the differences are very small and no trend can be identified. Similar comparisons for non-Muslim boys and girls show that fully exposed non-Muslims also have lower mean

[42]The non-parametric relationships are estimated by kernel-weighted local polynomial regressions of height-for-age Z-scores on age in months using an Epanechnikov kernel. Age in months is computed by using children's exact birth dates. In practice, I assign n to a child with n months and 0 to 14 days of age and $n+1$ to a child with n months and 15 to 30 days of age. The exposed children are exposed to Ramadan for a full month.

Z-scores compared to non-exposed non-Muslims by about a 0.10 standard deviation at all ages.

1.3.4 Econometric model

Graphical and tabular illustrations of the identification strategy show the impact of exposure to Ramadan on Muslim boys during late childhood; however, no visible impact on Muslim girls is detected. Given the implications of the illustrations of the identification strategy, I specify age- and gender-specific econometric models. Such models also control for background information, which is extensively available for child, mother, household and community. This is done in order to more accurately estimate the height effect of Ramadan-induced malnutrition in utero.

To estimate the effect of fetal malnutrition induced by exposure to Ramadan on Muslim children's height, measured by height-for-age Z-scores, I use OLS regressions controlled by a host of relevant regressors. I run separate regressions for boys and girls at every year of age. I also run the same regressions for non-Muslims as falsification tests. Non-Muslim regressions also allow testing for the possible effects of seasonality. Then, I combine data for Muslims and non-Muslims and recover the coefficients of the former regressions in an interaction regression. The specifications of the regressions are as follows:

$$
\begin{aligned}
Y_i &= \alpha^{BOY_j,M} + \beta^{BOY_j,M}.HER_i + \delta^{BOY_j,M}.X_i + \varepsilon_i^{BOY_j,M} && (1.1) \\
Y_i &= \alpha^{BOY_j,N} + \beta^{BOY_j,N}.HER_i + \delta^{BOY_j,N}.X_i + \varepsilon_i^{BOY_j,N} && (1.2) \\
Y_i &= \alpha^{BOY_j} + \beta^{BOY_j}(HER_i \times MOMMUSLIM_i) + \rho^{BOY_j}.HER_i \\
&+ \delta^{BOY_j}(X_i \times MOMMUSLIM_i) + \sigma^{BOY_j}.X_i \\
&+ \mu^{BOY_j}.MOMMUSLIM_i + \varepsilon_i^{BOY_j} && (1.3) \\
Y_i &= \alpha^{GIRL_j,M} + \beta^{GIRL_j,M}.HER_i + \delta^{GIRL_j,M}.X_i + \varepsilon_i^{GIRL_j,M} && (1.4) \\
Y_i &= \alpha^{GIRL_j,N} + \beta^{GIRL_j,N}.HER_i + \delta^{GIRL_j,N}.X_i + \varepsilon_i^{GIRL_j,N} && (1.5) \\
Y_i &= \alpha^{GIRL_j} + \beta^{GIRL_j}(HER_i \times MOMMUSLIM_i) + \rho^{GIRL_j}.HER_i \\
&+ \delta^{GIRL_j}(X_i \times MOMMUSLIM_i) + \sigma^{GIRL_j}.X_i \\
&+ \mu^{GIRL_j}.MOMMUSLIM_i + \varepsilon_i^{GIRL_j} && (1.6)
\end{aligned}
$$

where i indicates a child and j indicates the age of the child in years (each specification is estimated five times for $j = 0, 1, ..., 4$). M and N mark Muslims and non-Muslims, respectively. Y is the dependent variable of interest, i.e. height-for-age Z-score. HER is a set of exposure measures. It can be *HER279*, i.e. hours of exposure to Ramadan during entirety of gestation, $\{HERt_1, HERt_2, HERt_3\}$, i.e. hours of exposure to Ramadan during trimesters of gestation, or $\{HERm_0, HERm_1, ..., HERm_9\}$, i.e. hours of exposure to Ramadan during months of gestation. MOMMUSLIM is a dummy variable that indicates if the child's mother is Muslim. X is a set of control variables that consists of age in days, year of birth, month of birth, birth order, a variable that indicates twin birth, urban/rural indicator, an indicator of province or state of residence, parents' ages at child's birth, parents' education, mother's height, and household's wealth indicator.

The regressions are set such that the following equalities hold:

$\beta^{BOY_j} = \beta^{BOY_j,M} - \beta^{BOY_j,N}$ for $i = 0, 1, ..., 4$

$\beta^{GIRL_j} = \beta^{GIRL_j,M} - \beta^{GIRL_j,N}$ for $i = 0, 1, ..., 4$

The first equality uses the results of Equations 1.1, 1.2, and 1.3. The second equality uses the results of Equations 1.4, 1.5, and 1.6. Thus, the results of the estimations of Equations 1.3 and 1.6 can be used to test if Muslim versus non-Muslim differential effects are significant.

A mother's height is included among the control variables in order to address genetic effects. I also plug year and month of birth to address seasonality and other time related effects on height.[43] Parents' education, especially a mother's education, are also shown to be correlated with children's height (Behrman and Deolalikar 1988). It is also been shown that the effect of education on height is transmitted by access to information (Thomas *et al* 1991). Thus, I also control for parents' education.

In addition, in order to recognize the well-documented correlation between height and well-being, I also include an index of well-being among the regressors (Gowin 1919, Martorell and Habicht 1986). In order to create a uniform

[43]Researchers document the correlation of birth time (year, season, or month) with adulthood health outcomes, such as life span, older age mortality, and chronic conditions (Doblhammer and Vaupel 2001, Costa and Lahey 2005, Costa *et al.* 2007). In a *Nature* article, Weber *et al.* (1998) show sinusoidal variation in height by month of birth in Austria (taller if born in warmer months). Hennenberg and Louw (1993) made similar observations in South Africa. Buckles and Hungerman (2008) show that one's season of birth is correlated to the mother's socioeconomic characteristics.

index of wealth across all countries and samples from different years, I choose variables that display different aspects of a household's well-being and, also, ones that are reported in all of the samples. The variables are (i) source of drinking water; (ii) type of toilet facility; (iii) main floor material; (iv) access to electricity; (v) owning radio; (vi) owning TV. Then, I extract the principle component of the six variables and use its quintiles to generate an indicator variable (1: very poor, 2: poor, 3: average, 4: rich, 5: very rich).

1.4 Main Results

After estimating Equations 1.1-1.6 by age, the coefficient(s) of the effect of exposure to Ramadan during entirety, trimesters of, and months of gestation on height-for-age Z-scores are reported in Tables (3), (4), and (5), respectively. In the month regressions, I have also included hours of exposure in the month prior to conception, named month 0. This will allow for investigating the interaction between human eggs and its environment at pre-conception period.[44]

The results display almost no significant effect of exposure to Ramadan on height in the first two years of age for Muslim boys or for Muslim girls. Height effect starts to appear from the third year of age, i.e. age 2, 3, and 4. No early childhood height effect is consistent with the predictions of the fetal origins hypothesis and related experimental findings (Kusin *et al.* 1992, Roseboom *et al.* 2000, Gluckman and Hanson 2005, Eriksson 2006). For example, Kusin *et al.* (1992) find that differential height effects of late gestation nutritional interventions are less pronounced after birth and grow stronger with age.[45]

Despite Kusin *et al.* (1992), who find no sex difference in the height effect of late gestation nutritional intervention, the height effects of Ramadan-induced malnutrition in utero are gender-specific: few to zero effects are detected for girls, but strong effects are identified for boys (Tables 3-6).[46] Because of the

[44]Fleming (2011) extends studies of the developmental origins of health to the pre-fertilization period. He uses biological theories and argues that the pre-conception environment where human eggs forms can have short-term and long-term health consequences.

[45]The possibility of mis-measurement is also higher at the stage of very early childhood, when child "length"is usually reported (Floud *et al.* 1990, p. 243).

[46]Banerjee *et al.* (2007) also report significant causal height effect of prenatal/postnatal malnutrition, but they are merely focused on the males using military data.

major sex difference in the effect, I analyze the male and female separately.

1.4.1 Effect on boys' height

To make the results of regressions reported in Tables (3)-(5) sensible, I multiply them by 330(=11×30). Multiplied by 11 because the sample average of daylight hours in a Ramadan day is about 11. Further multiplication by 30 is to approximate the effect of a full month of exposure since about 80% of Muslims in the sample are exposed to a full month of Ramadan. I also focus on 3 and 4 year-old Muslim boys for whom Muslim versus non-Muslim differential effects are statistically significant.

Multiplied by 330 to indicate the effect of a full Ramadan exposure, the Muslim-specific effects (the results under the column named M in Table 1.3 at ages 3 and 4 translate to –0.11 and –0.10 standard deviations, respectively.[47] At the same ages, the sizes of Muslim versus non-Muslim differential effects of full exposure are –0.13 and –0.10 standard deviations, respectively. Using the standard deviations of the height of the children at the same ages in the WHO 2006 reference population, the results in terms of standard deviation can be converted to millimeters (mm). Then, the impacts translate to a 3.9mm-4.4mm decline in the height of Muslim boys at age 3, i.e. when the age is between 3 years and 0 days to 3 years and 364 days. Compared to non-Muslim boys at age 3, the magnitude of the negative effects rise to 4.9mm-5.5mm. At age 4, i.e. when the age is between 4 years and 0 days to 4 years and 364 days, the sizes of Muslim-specific and Muslim versus non-Muslim effects are both equivalent to a 4.1mm-4.5mm decline in height.

To account for the timing of exposure, I consider the results of trimester regressions in Table 1.4. Again, the effects of exposure start emerging at age 2, but the Muslim versus non-Muslim differential effect is still insignificant at this age. Strong effects are again found at ages 3 and 4. At age 3, effects of exposure to Ramadan at the first and third trimesters are statistically significant for Muslim boys. If full exposure during trimesters is considered, then the sizes of the effects are –0.15 and –0.10 standard deviations for first and third trimesters, respectively. These translate to a 3.6mm-4.0mm and 5.7mm-6.4mm decrease in height, respectively. At age 3, Muslim versus non-

[47] As expected, no effect on non-Muslims is detected.

Muslim differential effects are also significant at the same trimesters, translating to a 3.4mm-3.9mm and 7.6mm-8.6mm decline in height and caused by full exposure during the first and third trimesters, respectively. At age 4, when it is most expected to see the real effects of prenatal malnutrition on height, Muslim-specific and Muslim versus non-Muslim differential effects for all trimesters are significant with larger size at the second trimester, which is the most important trimester in terms of bone development. At this age, for a full exposure, the effects' size varies between –0.08 and –0.14, where the lower bound belongs to the first and upper bound belongs to the second trimester. The standard deviations translate to a 4.4mm-6.4mm decline in height.

Evaluating the effects of exposure to Ramadan by month delivers even more detailed information about the timing of exposure to Ramadan and its height consequences (Table 1.5). According to the results, no or negligible height effect in the first three years of life is detected. Similar to the trimester regressions, the differential effects are significant at age 3 and 4. At age 4, exposure to Ramadan at almost any month of gestation, even the month prior to conception, has statistically significant adverse effect on height. The Muslim versus non-Muslim effects are correspondingly significant. At this age, the stronger effects of exposure belong to months 3, 4, 5, and 7 of gestation. Similar patterns of monthly effects, at smaller sizes, are identified at age 3.

The times at which the effects are stronger are in accordance with the biological dynamic of fetal growth, described in Section 2.5, where two distinct phases were characterized. These include the pre-ossification or evolutionary phase during which the cartilage models and the primary ossification centers of long bones form (month 2 to 4) and the ossification or expansionary phase during which bone cells develop (from month 5 to birth, peaked at the second trimester). However, the differences of the effects at the two phases are not statistically significant. Thus, decreased growth potentials, derived from exposure in the first phase and abated bone cell generation, arose with exposure in the second phase, statistically have the same impact on height at late childhood.

Presenting a millimeter equivalent of height declines caused by full exposure to Ramadan during a month of gestation is unrealistic because the exact coincidence of Ramadan at a month of gestation is rare. However, knowing the effect of the hypothetical full exposure at some critical months is insightful. Month 0 (pre-conception month when the interaction of human eggs and environment can be evaluated), month 3 (the most productive period in the formation of the cartilage models), month 4 (the most productive period in the formation of the primary ossification centers), month 5 (when bones' cells start developing at high rates and general fetal growth rate is at its peak) are of particular interest. According to the results, a hypothetical full exposure at month 3 leads to a 9.2mm to 10.0mm decrease in the height of 4 year-old Muslim boys, compared to non-exposed Muslim boys. At months 4 and 5, similar comparisons show declines in height with sizes of 8.7mm-9.5mm and 8.6mm-9.4mm, respectively. The effect of preconception exposure is less strong. At age 4, a hypothetical full exposure to Ramadan about a month prior to conception results in a 7.5mm-8.2mm decline in the height of Muslim boys, compared to the Muslim boys who were not exposed.[48]

In addition, exposure to Ramadan in the first month of pregnancy has a significant effect on height at ages 3 and 4. For the first month, the stem cells that make the foundation of cartilage models migrate toward bone locations and start concentrating. The height effect of exposure to Ramadan during the first month of gestation is of special interest because pregnancy is usually not realized during the first month. In this case, a higher observance rate of Ramadan is expected.

In summary, if full exposure at entirety and trimesters of gestation are considered, then the size of the negative effect of exposure to Ramadan on height is between 3.4mm to 8.6mm at age 3 and between 4.1mm to 6.4mm at age 4 when exposed Muslim boys are compared to non-exposed Muslim boys and non-Muslim boys. However, the negative effects amount to about 10mm in the hypothetical cases of full exposure at months 3, 4, 5, and 7 of gestation.[49]

[48] I have run the regressions for entirety, trimesters of, and months of gestation regressions without control variables and with inclusion of any of them. The results demonstrate that none of the control variables change the pattern of the results, and the height impacts of exposure hold in all regressions.

[49] The range of the results are comparable to the findings of Banerjee *et al.* (2007). They estimate the effect of income shocks at the year of birth on height at age 18 and measure 6mm-10mm negative effects.

1.4.2 Effect on girls' height

For girls, no height effect of exposure to Ramadan is detected from entire gestation regressions (Tables 3). Trimester and month regressions, however, illustrate some significant effects (Tables 4 and 6). Exposure at some late gestation months is associated with a decrease in height/length in the first year after birth. Apart from this, exposure during the month prior to conception and the last month of gestation are seen to have negative effects on height at age 3 and 4. Furthermore, month regressions do not show consistent effects on girls' height, and the few detected effects do not follow a specific pattern. The effects in the first year are not only prone to mis-measurement but also cannot be taken as strong signs of growth deficiency in the future. Also, the effect of exposure during the last month of gestation has the least relevance to biological growth facts.

Before jumping to the conclusion that prenatal malnutrition induced by exposure to Ramadan has no adverse height consequences for girls, I conducted another test. As demonstrated by what follows, I investigate the effect of exposure to Ramadan on children's mothers' height. The idea is that if no sign of height deficiency is detected during stages of late childhood, given the fact that the correlation between height at late childhood and ultimate height is beyond 80%, then it is not expected to discern the height effect of in utero exposure to Ramadan in adulthood.

To run mothers' height analyses, I utilize information from the same data samples. In DHS data samples, in addition to children's anthropometrics, mothers' anthropometrics are reported. But, mothers' day of birth is not reported. Without the day of birth, it is not possible to analyze the height effects of exposure to Ramadan by its exact timing. This compromises the analysis of the effects of exposure in the first and last month of gestation, and it makes the boundaries of gestation months imprecise. Nevertheless, mid-gestation analyses, which are of particular importance in terms of height, are not expected to change dramatically. Hence, the results of entirety and trimesters of gestation regressions will generally remain valid.

In practice, I run econometric models similar to Equations 1.4 to 1.6 with a few differences. First, I cannot include mothers' mothers' height and mothers' parents' educational attainment among the control variables because they are unavailable.[50] Second, since WHO 2007 adults' reference population does not go beyond the age of 19, I use the standards for a 19 year-old woman to compute the Z-scores for mothers of 20 years of age and more. Thus, mothers' Z-scores are not as precise as children's Z-scores.[51] Third, I do not run age-specific regressions for mothers because (i) there are very rare cases with mothers below the age of 15; (ii) the majority of mothers are at age 19 or older; (iii) young adults' height growth is slow, especially after the *peak growth velocity during puberty*, which occurs between the ages of 13 and 15 (Beard and Blaser, FIGURE 3A). Fourth, I compute the hours of exposure to Ramadan, assuming that mothers are born at the 15th of their corresponding month of birth.[52]

The results of mothers' regressions are reported in Table 1.7. According to the results, exposure to Ramadan, either measured by hours or by days, has no effect on mothers' height. Estimating no height impact for mothers accords with estimating no height impact for female children. As it is now reconfirmed, Ramadan-induced nutritional disorder has no effect on the height of females although males are very vulnerable to such nutritional disorders. This result is in agreement with the previously documented finding that female-to-male ratio rises as a result of malnutrition in utero and provides a unique causal evidence of afterbirth sex differences in height growth in support of the fragile man hypothesis.

However, finding no effect on females' height is in contrast with the findings of Maccini and Yang (2009) and Akresh *et al.* (2011). They use variations in rainfalls and crop failures across time and space in Indonesia and Rwanda, respectively, to estimate the health effects of nutritional insufficiency at the year of birth. They find that only women's height is affected by the shocks and suggest gender bias as an explanation. Since gender bias is mainly effective after a child's birth, it is not likely that gender bias contaminates the measuring of the effect of exposure to shocks in utero, especially when

[50]Inclusion of mothers' height and parent' education among the control variables does not change the pattern of the effects on children. Subsequently, I do not expect a lack of these control variables in mothers' regressions to distort the results.

[51]Limiting mothers' anthropometric standards to those for a 19 year-old woman is not expected to cause substantial measurement errors because the rate of body height growth is very slow from age 20.

[52]The results of these analyses do not change by changing the day of birth to any of the numbers in the range of 10 to 20. Thus, I only report the result of regressions in which I have assumed the 15th to be all mothers' day of birth.

prenatal and postnatal malnutrition can exactly be differentiated. As it is found in this section, the absence of such unobservable factors results in documenting the difference of sexes in carrying the height effect that fits to medical facts.

1.4.3 Robustness tests

The height effects are biased if parents set the timing of pregnancy with respect to Ramadan. To address this concern, I use controlled regressions to evaluate the effect of parents' and households' characteristics on hours of exposure. The results of such regressions do not show that parents systematically set the timing of conception according to occurrence of Ramadan. I also check if the results hold under alternative measures of exposure to Ramadan, which are computed based on days of exposure, and find comparable results.

I run further robustness tests, but these results are not reported for the sake of space. To check if the results are driven by observations from a specific country, I rerun the regressions (Equations 1.1-1.6), dropping any of the countries that are over-represented in the sample. These countries are Bangladesh, India, Egypt, and Nigeria. The results do not show dramatic changes in the size and pattern of the effects. In addition, I rerun Equations 1.1 to 1.6, including mothers' fixed-effects, to control for household-level unobservable factors that may correlate with decisions to get pregnant or to fast during Ramadan. In such regressions, comparing siblings of the same mother drives the identification. In this case, one child was exposed to Ramadan in utero and the other was not. Again, the pattern of results does not change, and the size of coefficients only change minimally. I also reestimate the regressions using the exposure measures that assume different lengths of gestation, e.g. 261 and 270 days, and obtain similar results.[53]

To show that how the height effects would be mismeasured in lack information about children's day of birth, I reestimate the height effects by assigning specific days of birth to all children. The results demonstrate that unavailability of day of birth can result in sizable overestimation or under-

[53] If gestation lasts for 270 days, durations of trimesters and months of gestation are 90 and 30 days, respectively. But, if gestation lasts for 261 days, durations of trimesters and months of gestation are 87 and 29 days, respectively.

estimation of the real effect. The size of the measurement error is bigger if day of measuring height is also missing.[54]

1.5 Further investigation of the Ramadan effect

I have so far shown that Ramadan-induced malnutrition in utero has adverse height effects on male children. In this section, mainly focused on boys, I examine the details of this relationship. More specifically, I consider how adjustments in the intensity of exposure change the effect, if the effect transmits from mothers to children, how shifts in latitude alter the effect, and if the effect is reversible.

1.5.1 Adjusting the intensity of the effect

In Section 4.1, in order to evaluate the effect of a full month's exposure to Ramadan, I multiplied the estimated coefficients for an hour of exposure by 330. This practice, however, does not address some important aspects of the issue. First, the height effects may not be linear. Second, it is unclear if adjusting the intensity of exposure still renders the effects on girls' and younger boys' height insignificant. Therefore, in this section, I examine the height effects of full and partial exposure to Ramadan during the entire gestation period.

In practice, I estimate Equations 1.1-1.6 but replace the exposure measure(s) by an index measure that takes four values: 0 if there is 0 days of exposure, 1 if there is/are 1 to 10 day(s) of exposure, 2 if there are 11 to 20 days of exposure, 3 if there are 21 to 30 days of exposure.[55] The results of the regressions illustrate clear impacts of change in the intensity of exposure

[54]Height studies generally suffer from this measurement error. Even the studies that focus on in utero environment and provide estimates of adverse height effects of malnutrition in utero, e.g. Brainerd and Menon (2012) and Rosales (2013), endure the problem. Although Ramadan studies do not examine height, but their analysis of other outcomes suffers from the measurement error at times. For example, Almond and Mazumder (2011)'s analyses that use data from Iraq and Uganda and Almond *et al.* (2012)'s analyses that use Muslim children's test scores in the U.K. suffer from the problem. However, Almond and Mazumder (2011)'s analyses that use Michigan natality data and van Ewijk (2011) and Majid (2012) studies that use Indonesian Family Life Surveys use exact birth dates.

[55]Changing the cutting points of days of exposure around these values does not change the pattern of results.

(Table 1.8). For boys, the strongest effects appear at ages 3 and 4 again, although the pattern of the effects is not linear. Still no significant effect is identified for girls. Thus, to save space, I have not reported the results of girls' regressions.

It is worthwhile to scrutinize the pattern of height effects by intensity for boys who are at ages 3 and 4. First, exposure for 1 to 10 days have no statistically significant adverse height effect for 3 year-old or for 4 year-old Muslim boys. Second, for 3 year-old boys, the Muslim versus non-Muslim differential effect is significant only if the child is exposed for more than 20 days. Third, for 4 year-old boys, the effect is significant for both ranges of 11-20 and 21-30 days of exposure. In addition, a decrease in the size of effect, from the range 11-20 to 21-30, is observed. This indicates that after being exposed to Ramadan for more than 10 days, the marginal effect of further exposure decreases. This result will be confirmed in Section 5.3 where the latitude effect is investigated, leading to the hypothesis that the Ramadan effect is derived by a combination of mere dietary distortion and some fasting.

1.5.2 Transmission of the effects

In this section, I examine the intergenerational transfer of height effect caused by Ramadan-induced prenatal malnutrition. I investigate if a mother's own experience of malnutrition in utero can cause shortness in the height of her offspring. Additionally, I consider whether a mother's own malnutrition in utero exacerbates the height effect of children's malnutrition in utero.[56]

To answer these questions, I examine the effects of exposure of both chil-

[56]The literature of intergenerational transfer of anthropometric deficiencies, which are induced by environment rather than genetics, is narrow and new. In fact, there is sparse empirical evidence in this regard. Mainly because the required data is inaccessible or unavailable, the scarce attempts have usually been spent just to draw correlations. Conley and Bennett (2001), for example, use the Panel Study of Income Dynamics (PSID) and find that the probability of a child's low birth weight can be predicted by a mother's birth weight and the household's income at birth. Currie and Moretti (2007) use California birth records to find that mothers who were born with low birth weight are more likely to give birth to low birth weight babies. There are two recent studies that try to shed light on the causal intergenerational effects of environmental adversity during gestation or childhood. First, Painter *et al.* (2008), using the Dutch famine as a natural experiment, found no relationship between parents' in utero and childhood exposure to the famine with the risk of low birth weight and cardiovascular and metabolic diseases in children. Caruso (2013) uses floods in Tanzania to show that a mother's exposure during childhood and early adulthood reduces her own height and that of her children as well.

dren and mothers to Ramadan on children's height-for-age Z-scores. I limit this analysis to Muslim boys because I have shown so far that girls are not likely to bear the height effects of fetal malnutrition. In principle, I estimate Equation 1.1, but I use indexes of exposure to Ramadan instead of measures of hours and days of exposure. Indexes of exposure are dummy variables that take the value 1 if any exposure has happened during gestation and 0 otherwise. The reason to use the indexes is to achieve straightforward interpretations from the interaction terms. Thus, in addition to the indexes of children's and mothers' exposure to Ramadan, interaction terms of the two sets of indexes are included in the regressions. This is to evaluate whether mothers' exposure exacerbates the effect of children's own exposure.[57]

The estimated coefficients of the exposure indexes, during entirety and trimesters of gestation, as well as the interaction terms are provided in Tables (9) and (10), respectively. At each year of age, the results are given in three columns. In the first column, only the effect of children's exposure, measured by the index of exposure, is examined. The results confirm that the generated outcomes from index regressions are consistent with the outcomes from hours and days regressions. In the second column, the effect of children's and mothers' exposure are examined. In the third column, the interaction term(s) is/are also included. If it is expected that mothers' height loss, derived from their exposure to Ramadan, be transmitted to their children, then the coefficients of mothers' exposure, or the interaction terms, should be statistically significant, especially at ages 3 and 4 when the differences start to appear. Virtually, neither entire gestation regressions nor trimester regressions display transmission effects. The few significant coefficients of mothers' exposure indexes in the trimester regressions at ages 1 and 2 cannot be taken seriously because none of the children's own exposure indexes illustrate any significance at those ages.[58]

The findings of this section, i.e. no intergenerational transfer of Ramadan effect from mothers to children, is consistent with the findings of Section 4.2,

[57]In Section 5.1, I mentioned that the index of exposure is not the best measure of exposure to Ramadan because it does not account for the level of exposure. However, I have used them in the transmission regressions since they are more suitable for this purpose.

[58]Using alternative measures of exposure to Ramadan, i.e. days and hours of exposure during entire gestation, in similar regressions also does not result in significant intergenerational effect(s).

where no height effect of exposure to Ramadan was identified for the female children and adults. In fact, if females do not carry the adverse height effects of exposure to Ramadan during their fetal life, then it is also not expected that they transfer such an effect to their children.

1.5.3 Latitude effect

The length of a Ramadan day, which determines the time span of fasting for that day, is itself determined by latitude. In high latitude locations, the length of a day considerably varies in the course of a year. For example, at the northern latitude degree of 40, where Istanbul (Turkey), Baku (Azerbaijan), and Tashkent (Uzbekistan) are approximately located, the daylight hours of the longest days are about 5.6 more than those on the shortest days of a year (14.8 hours versus 9.2 hours). The difference gradually diminishes toward the equator, such that the length of a day does not change during a year at equator locations.[59]

The timing of Ramadan during a given year is not fixed. Since it is a lunar month, it comes about 11 days earlier every year, such that it takes about 32 years to have a full rotation of Ramadan across solar years. Therefore, Ramadan may come about mid-summer, when the days in high latitude locations are longer than the days in low latitude locations. It may also occur mid-winter, when the relationship is inversed. As a result, Muslims living at different latitudes do not experience a specific Ramadan day at the same intensity. The accumulative difference in daylight hours is immense. For example, a three-hour daily difference amounts to the remarkable magnitude of 90 hours in a month. The inevitable question, then, is how the effect of exposure to Ramadan varies by latitude. In this section, I suggest a statistical framework to answer this question.

First, I divide the observations among eight latitude ranges: 5°S plus, 5°S-5°N, 5°N-10°N, 10°N-15°N, 15°N-20°N, 20°N-25°N, 25°N-30°N, 30°N plus. The specific latitude ranges are selected in order to have a sufficient number of Muslim and non-Muslim boys and girls at each age (Table11). I define

[59] At latitude 30°N, i.e. 30 degrees north, where Cairo (Egypt), Amman (Jordan), and Casablanca (Morocco) are approximately located, the difference is about 4 hours. And, at latitude 15°N, where most parts of Senegal, Mali, Burkina Faso, Niger, and Chad are located the difference is about 2 hours.

dummy variables for each latitude range that take the value 1, if a child is surveyed in the latitude range, and 0 otherwise, $L_1, L_2, ..., L_8$, respectively. Then, I run regressions in which latitude dummies are interacted with the measures of exposure to Ramadan and the control variables. In effect, I add the interaction terms to Equation 1.3 and 1.6 for boys and girls, respectively, and run the corresponding regressions.[60] More specifically, I interact each latitude dummy to days of exposure, to days of exposure times Muslim dummy, and to Muslim dummy, but the coefficients of the second interaction (i.e. $L_l \times \mathit{DER279} \times \mathit{MOMMUSLIM}$ for $l = \mathit{1}, \mathit{2}, ..., \mathit{7}$) are my primary interest.[61]

The estimated coefficients of the triple interaction term are reported in Table 1.12. The latitude dummy for the equatorial range, taken as the reference range, is dropped from the regressions. The data samples of the high latitude countries are collected from the mid-1990s when Ramadan took place during late fall and early winter (shortest Ramadans). The data samples of the middle and low latitude countries are gathered from 1990 to 2011 and include long and short Ramadans. This feature of the data is reflected in the children's average hours of exposure by latitude range. For the exposed children from households in a place on latitude 5°S plus, 5°S-5°N, 5°N-10°N, 10°N-15°N, 15°N-20°N, 20°N-25°N, 25°N-30°N, and 30°N plus, the average hours of exposure during gestation are 342, 330, 325, 318, 309, 304, 299, and 293, respectively. Hence, if latitude has a role, then it is expected that the size of the latitude specific effects will be lower at higher latitudes. The results, however, show no sign of latitude effect.[62]

No latitude effect can be interpreted by a pregnant mother's response to the length of Ramadan days. For example, if a pregnant woman wants to

[60] I use a version of Equations 1.3 and 1.6 in which exposure to Ramadan is measured in days during the entire gestation, i.e. *DER279*. The choice of daily measures over hourly measures is deliberate. In fact, to compute hours of exposure to Ramadan, I have used the corresponding latitudes; while days of exposure to Ramadan are not affected by latitude. Hence, I do not use hourly measures in order to avoid a double counting of latitude effects.

[61] I have all of the single and double terms in the regressions.

[62] Differential latitude effects, also, cannot be identified in alternative regressions where smaller and larger latitude intervals are applied. I have examined the following sets of latitude dummies in separate regressions and have not detected influence of latitude: {4°S plus, 4°S-4°N, 4°N-8°N, 8°N-12°N, 12°N-16°N, 16°N-20°N, 20°N-24°N, 24°N-28°N, 28°N plus}, {6°S plus, 6°S-6°N, 6°N-12°N, 12°N-18°N, 18°N-24°N, 24°N-30°N, 30°N plus}, {10°S-10°N, 10°N-20°N, 20°N plus}, {15°S-15°N, 15°N plus}, and {0°N-20°N, 20°N plus},{10°S-20°N, 20°N plus}. Also, the impact of latitude cannot be identified in the latitude regressions that only use Muslims' data.

fast, then she might fast for fewer days if it is a long Ramadan. Moreover, if the Ramadan's effect is mainly derived by the dietary distortion induced by Ramadan rather than fasting, then the marginal effect of latitude on top of the main effect cannot be sizable. To investigate further on the effect of latitude, I run the same regressions, replacing the previous indicator of exposure, i.e. days of exposure during entire gestation (*DER279*), with days of exposure to Ramadan during the first month of gestation (*DERm1*), which is the month that pregnancy is less likely to be realized. Hence, mothers do not get the chance to respond to the length of Ramadan days, and they actually are more likely to fast, not knowing that they are pregnant. Therefore, if latitude has any effect, it should be detected in these new regressions. However, no latitude effect of exposure to Ramadan during the first month of gestation is identified, leading to the conclusion that intense fasting does not induce Ramadan's effect (results not reported).

The no latitude effect finding is in accordance with the findings of Section 5.1. It examined the impact of the change in the intensity of exposure in terms of day. Marginal adjustments in the intensity of exposure to Ramadan either by the number of days or by the latitude does not change the height effect. Thus, it can be concluded that the Ramadan effect is actually induced by partial fasting or/and the fasting environment that induces distortions in a pregnant woman's diet.

1.5.4 Reversibility and catch up

Another question is if the height deficiency induced by malnutrition in utero is reversible and whether the suffered Muslim boys can catch up the lost height. There is no definite answer to this crucial question in lieu of empirical studies that apply randomized recovery treatments on those who are affected by prenatal malnutrition and follow up with the subjects throughout their childhood. Thus, the answer should be sought in the implications of child development studies, experiments on animals, and biological explanations of the dynamics of human growth. In what follows, I argue that evidence from these three sources implies that height loss originating from prenatal malnutrition is irreversible. This claim gestures toward the importance of maternal nutrition during pregnancy, especially for the first two trimesters.

Child development literature shows that the earlier a nutritional insult occurs the less the chance of catch-up growth in height (Martorell *et al.* 1994, Martorell 1999, Rasmussen 2001). Victoria *et al.* (2010) show that height defects in children between 0 and 24 months remain permanent. Subsequently, it is expected that the likelihood of reversibility of height deficiency caused by malnutrition in utero to be minimal, even at the presence of a favorable afterbirth environment.

Animal studies try to simulate human growth in animals.[63] Considering the stages of development, researches simulate shocks to the human fetal environment by shocks to the newborn animals and find irreversible growth impacts (Strauss 1997, Lanham *et al.* 2011).

From the fetal origins point of view, malnutrition in utero propels the fetus to develop a thrifty stature as a survival strategy. Either it is a choice implied by fetal origins hypothesis or mere insufficiency of energy and nutrients for fetal development in length. In either case, fetal malnutrition impedes the vital process of cellar differentiation and multiplication. Consequently, the generated number of cells will be less in organisms, depending on the timing of malnutrition occurrences. With a decreased number of cells, the growth potential of the child will diminish.

1.6 Conclusion

In a detailed analysis of the effect of nutritional insult in utero on height, I employ exposure to the Islamic fasting month of Ramadan as a natural experiment seeking for a causal relationship between the two variables. I use all available DHS samples and observations that qualify for this measurement and analyze some unknown aspects of exposure to Ramadan in utero as well.

Consistent with the accumulative nature of height formation and in line with the prediction of the fetal origins hypothesis, I identify the first signs of height effects of Ramadan-induced malnutrition in utero with some delay and at age 2. The effects become stronger and more significant henceforth. Such effects, however, are found in male children. Also, no effect on the

[63]The most popular animals in such studies are rats because of the similarities of the early stages of their development with those in the human. Lambs and pigs have also been subjected to these types of studies.

height of the mothers of children is detected. Finding no female height effect provides a unique causal evidence of sex differences in affliction, supporting the fragile man hypothesis.

More specifically, I find that a full 30-day exposure to Ramadan during gestation, regardless of the timing of exposure, causes an approximate 4mm-5.5mm decline in height of 3 and 4 year-old exposed Muslim boys when compared to the non-exposed Muslim boys and non-Muslim boys. Decomposing the effect to trimesters of gestation shows statistically significant effects at all trimesters of gestation at age 4, when it is more likely that height differences become apparent. At this age, height decline is measured between about 4.4mm-6.4mm.

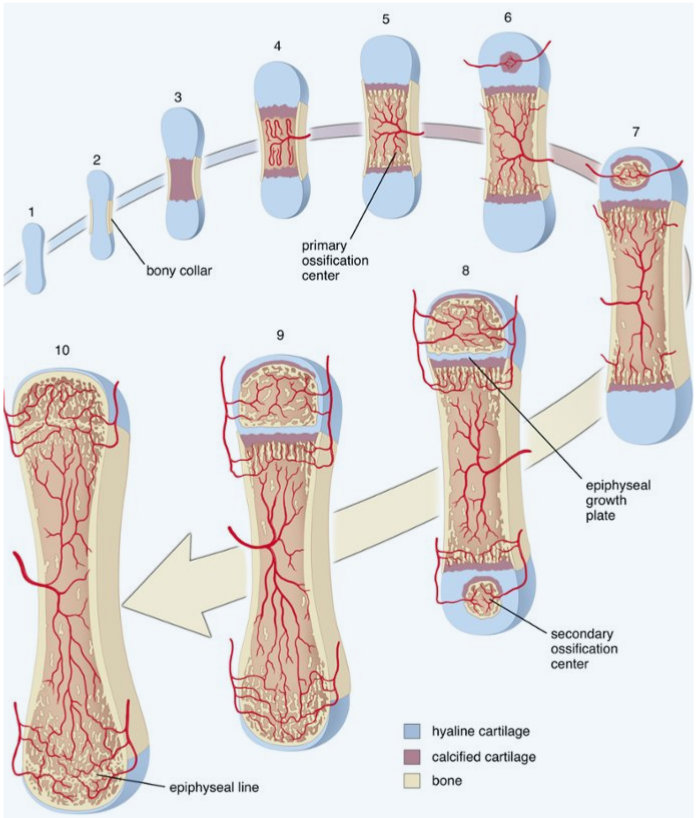
Further decomposition of the height effect to months of gestation is more revealing, such that the peaks of the effect coincide with the crucial windows of fetal development of long bones that lay the potentials growth in height. At age 4, the largest effects are found at month 3 (when the cartilage models develop at their highest rates), months 4 (when the primary ossification centers develop), and month 5 and 7 (when bone cells develop at accelerated rates). In a hypothetical situation when Ramadan coincides with any of these months, the effects for an average 4 year-old Muslim boy compared to a non-exposed Muslim boy and non-Muslim boy amounts to 7.5mm-10.5mm. The effect of pre-conception malnutrition on height is also found to be significant, and around 8mm in size, highlighting the importance of the interaction between human eggs and environment.

My research finds that mothers do not transmit Ramadan-induced height effect to their children. This conclusion is in line with the finding that female children and mothers bear no height effect from exposure to Ramadan. Assessing adjustments in the intensity of exposure shows that the effect appears after 10 days of exposure, but the size of marginal effect declines thereafter. In addition, latitude analyses do not show a significant impact of latitude on the results. These two pieces of evidence imply the presence of a combination of two types of distresses on pregnant Muslim women during Ramadan: (i) "partial" observance as a result of mothers response; (ii) dietary disorders, not fasting, imposed by the household and community.

Finally, I argue that there is no or a very limited likelihood that the height defects can be reversed. As a result, the measured height losses will remain permanent, and convey other health problems, and labor market disadvantages. Therefore, the findings of this study highlight the importance of informing pregnant women about the irreversible health impacts, caused by persistent meal skipping, diseases and infections at critical windows of fetal development. In the Muslim world, such polices need to be combined with efforts to persuade Islamic authorities to issue fatwas that "completely"exempt pregnant women from fasting.

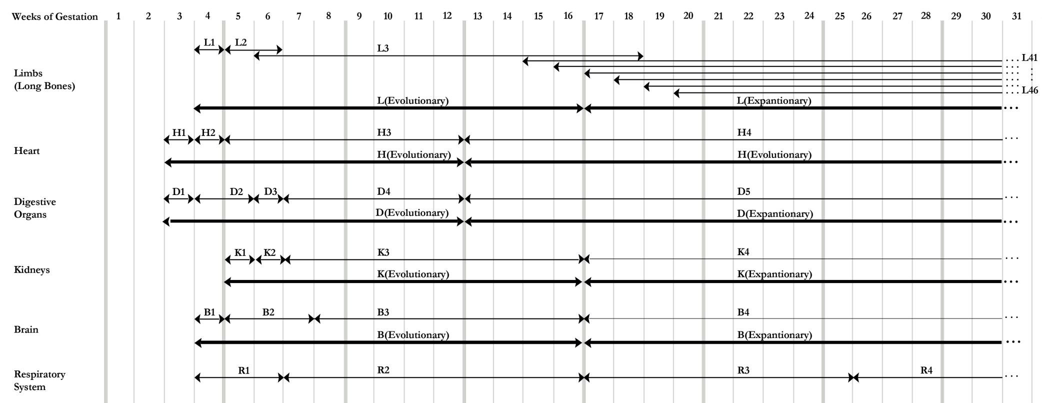
The findings of this study offer numerous domains for further research. While I examine the height effects of the fetal nutritional limitations, researchers should examine height effects of fetal nutritional supplementation to test if possible improvements mirror the documented deteriorations. Another line for investigation would be to evaluate the transmission of height effects from fathers to children. Also, latitude effect requires an updated evaluation when larger DHS samples from high latitude countries from the early 2010s, when Ramadans coinciding with summer, become available. Providing experimental evidence for the hypothesis of irreversibility of height effects of malnutrition in utero is another area for further investigation.

Figure 1.1: Schematic diagram of developing a long bone



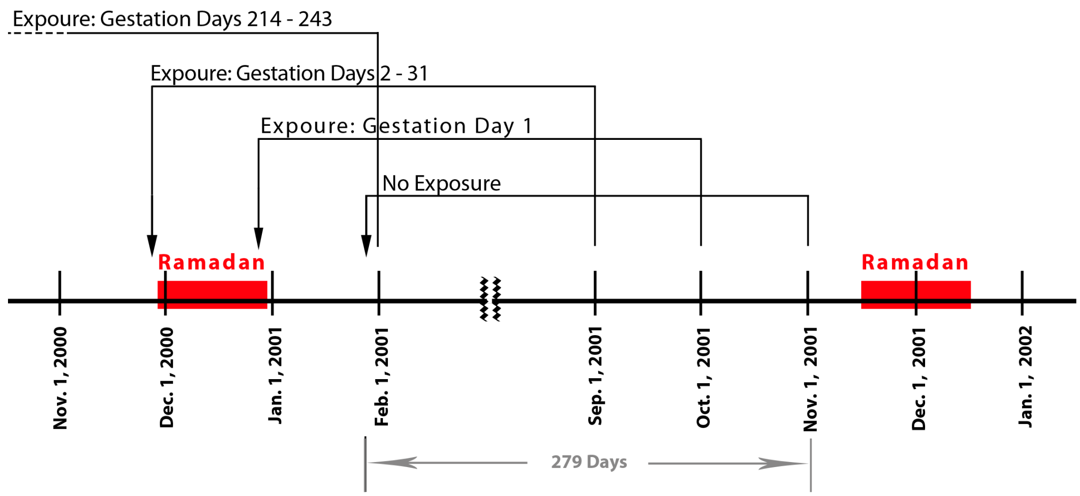
Notes: The illustrations on the figure, numbered from (1) to (10), show the stages of development of a long bones. Illustrations (1)–(4) show the chondrification stage. Illustrations (2)–(5) show the formation of primary ossification centers. Illustrations (5)–(6) show early endochondral ossification. After birth, long bones' development continues, shown by Illustrations (7)–(10). The illustrations that show pre-birth development can also be divided into two phases: pre-ossification phase (Illustrations 1–5) and ossification phase (Illustrations 5–6). Phase one starts about the end of the first month and closes about the end of the forth month of gestation. Phase two starts right after phase one and continues until birth.
Source: Rose and Pawlina (2010), Figure 8.17.

Figure 1.2: Critical windows development of limbs and vital organs



Notes: This figure shows the critical windows of development of vital organs and systems during the weeks gestation. It is intended to exhibit how critical windows of development of the limbs, especially the long bones that lay the potential for the ultimate growth in height, overlap with critical windows of development of other organs. To better show the overlaps, for each organ, the critical windows are also categorized as “evolutionary”and “expansionary”phases and shown underneath them. The critical windows of development of the limbs are named as *L1*, *L2*, *L3*, *L41*, *L42*, *L43*, *L44*, *L45*, and *L46*, which indicate the episodes of appearance of limb buds; mesodermal condensation; chondrification and formation of the primary ossification centers; ossification of ischium; ossification of calcaneous; ossification of arms’ long bones; ossification of legs’ long bones; ossification of scapula and ilium; ossification of publis, respectively. The critical windows of development of the heart are named as *H1*, *H2*, *H3*, and *H4*, which indicate the episodes of formation of bilateral cardiogenic areas and fusion of the heart tubes; beginning of the heart beat and completion of the heart looping; separation of artia, formation of coronary sinus, completion of semilunar valves, and development of atrioventicular valves; growth of the completed heart in size alongside the growth of fetus, respectively. The critical windows of development of the digestive system are named as *D1*, *D2*, *D3*, *D4*, and *D5*, which indicate the episodes of formation of the gut tube; formation of the stomach and its rotation, appearance of the liver bud and of ventral and dorsal pancreatic buds; formation of the liver; formation of the intestine and ascending and descending colons; growth of the formed digestive system in size alongside the growth of fetus, respectively. The critical windows of development of the kidneys are named as *K1*, *K2*, *K3*, and *K4*, which indicate the episodes of formation of the initial kidney cells (metanephric blastema) and ureteric buds at each side of the body axis; growth of the ureteric buds and their connection to, growth, and bifurication inside the grown metanephric blastema; extensive bifurication and the kidneys’ ascending from their original sacral location; expansion and completion of the collecting duct system, respectively. The critical windows of development of the brain are named as *B1*, *B2*, *B3*, and *B4*, which indicate the episodes of bending of the early brain; subdivision of the brain’s vesicles and appearance and expansion of cerebral hemispheres; development of pons; appearance and expansion of the complex patterns of lobes and gyri in the cerebral hemispheres, respectively. The critical windows of development of the respiratory organs such as lungs are named as *R1*, *R2*, *R3*, and *R4*, which indicate the episodes of appearance of the lung buds and branching of larynx, trachea, bronchides, and lower airways including aveloi; pseudoglandular stage of lungs development; canlicular stage of lungs development; aleveolar/saccular stage of lungs development, respectively.

Figure 1.3: Graphical illustration of calculating days of exposure to Ramadan during gestation



Notes: The figure shows how exposure to Ramadan is calculated. Ramadan in 2000 began on November 28 and ended on December 27 (the left rectangle on the time line). In 2001, Ramadan began on November 17 and ended on December 16 (the right rectangle on the time line). Assuming that Ramadan does not impact the length of gestation, all gestations are presumed to be normal and last 279 days. Four hypothetical birth dates are taken on the time line: 11/1/2001, 10/1/2001, 9/1/2001, and 2/1/2001. Moving backward from the birth dates by 279 days, the corresponding dates of conception are found on the time line, pointed by arrow signs on 1/27/2001, 12/27/2000, 11/27/2000, and 4/29/2000, respectively (the last conception date cannot be shown in the figure because of limited space). As it is presented on the figure, a gestation period ending on 11/1/2001 has no overlap with Ramadan. However, gestation periods ending on 10/1/2001, 9/1/2001, and 2/1/2001 overlap with Ramadan at day 1, day 2 to 31, and day 214 to 243. If the length of the particular gestation periods go below or beyond 279 days, the timings of exposure are misclassified. However, as it is discussed in the empirical analyses, such misclassification do not change the size and pattern of results.

Figure 1.4A: Height-for-age Z-scores by months of age and exposure to Ramadan (Muslim boys)

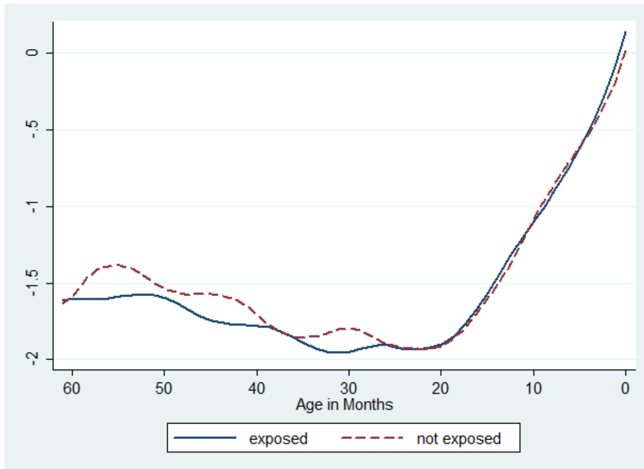
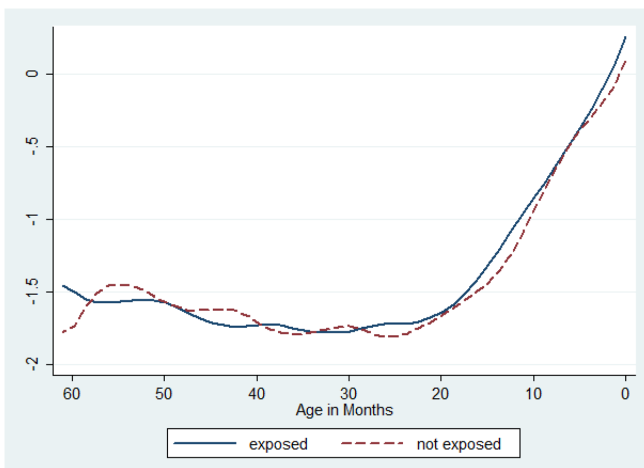


Figure 1.4B: Height-for-age Z-scores by months of age and exposure to Ramadan (Muslim girls)



Notes: These figures are presented to illustrate the empirical strategy of this paper. The figures show the kernel-weighted local polynomial regressions (using Epanechnikov kernel) of height-for-age Z-scores on months of age. Age in months is computed by using children's exact birth dates. It is assigned n for a child with n months and 0 to 14 days of age and $n+1$ for a child with n months and 15 to 30 days of age. The exposed children are those who were exposed to Ramadan in utero for a full month.
Data Source: Demographic and health surveys of MEASURE DHS project.

Table 1.1: Number of observations from countries in the pooled sample by religion and gender

		Muslims			Non-Muslims		
	Country	All	Boys	Girls	All	Boys	Girls
1	Albania	788	384	404	151	81	70
2	Azerbaijan	1,743	933	810	5	2	3
3	Bangladesh	18,634	9,526	9,108	2,004	1,026	978
4	Benin	657	349	308	4,634	2,300	2,334
5	Burkina Faso	5,913	3,024	2,889	3,979	2,001	1,978
6	Burundi	90	47	43	2,309	1,180	1,129
7	Cameroon	1,204	616	588	4,612	2,277	2,335
8	Central Afr. Rep.	181	84	97	1,509	765	744
9	Chad	3,254	1,579	1,675	2,328	1,202	1,126
10	Comoros	467	248	219	0	0	0
11	Egypt	23,998	12,262	11,736	1,138	624	514
12	Ethiopia	5,144	2,675	2,469	8,607	4,371	4,236
13	Gabon	144	83	61	1,745	855	890
14	Ghana	736	397	339	4,063	2,024	2,039
15	Guinea	1,773	919	854	271	146	125
16	India	5,047	2,628	2,419	32,454	17,207	15,247
17	Jordan	5,296	2,709	2,587	87	38	49
18	Kazakhstan	490	229	261	174	82	92
19	Kenya	1,101	592	509	7,632	3,801	3,831
20	Kyrgyzstan	830	429	401	63	40	23
21	Liberia	296	177	119	2,287	1,194	1,093
22	Malawi	2,393	1,181	1,212	13,809	6,898	6,911
23	Maldives	979	472	507	0	0	0
24	Mali	13,703	6,930	6,773	1,259	639	620
25	Morocco	4,454	2,259	2,195	0	0	0
26	Mozambique	1,958	957	1,001	10,891	5,440	5,451
27	Niger	2,993	1,561	1,432	30	13	17
28	Nigeria	7,999	3,933	4,066	6,893	3,530	3,363
29	Senegal	2,915	1,529	1,386	101	45	56
30	Sierra Leone	977	486	491	312	151	161
31	Tanzania	3,579	1,810	1,769	5,795	2,921	2,874
32	Togo	377	184	193	2,174	1,072	1,102
33	Turkey	1,897	1,031	866	8	3	5
34	Uganda	809	410	399	5,315	2,650	2,665
35	Uzbekistan	890	458	432	22	9	13
	Total	123,709	63,091	60,618	126,661	64,587	62,074

Data Source: Demographic and health surveys of MEASURE DHS project.

Table 1.2: Summary statistics of independent and dependent variables for boys

	Muslims			Non-Muslims		
	No. Days of Exposure:			No. Days of Exposure:		
	0	1 to 29	30	0	1 to 29	30
Panel A: Parent's and Household's Characteristics						
Birth Order	3.47	3.40	3.44	3.37	3.39	3.38
	(2.40)	(2.38)	(2.38)	(2.27)	(2.30)	(2.30)
Mother's Education	3.91	4.04	3.94	4.51	4.58	4.52
	(4.81)	(4.82)	(4.85)	(4.66)	(4.50)	(4.49)
Father's Education	5.00	5.03	4.94	6.19	6.29	6.22
	(5.44)	(5.44)	(5.41)	(4.83)	(4.80)	(4.77)
Mother's Age at Birth	26.50	26.37	26.39	26.36	26.57	26.44
	(6.56)	(6.46)	(6.47)	(6.25)	(6.38)	(6.34)
Father's Age at Birth	35.52	35.47	35.44	33.28	33.38	33.48
	(9.85)	(9.87)	(10.05)	(9.12)	(9.22)	(9.24)
Mother's Height	157.30	157.22	157.33	156.27	156.14	156.28
	(6.95)	(7.07)	(7.05)	(6.91)	(6.96)	(7.01)
Urban (%)	33.45	35.10	34.41	26.77	27.89	26.98
Twin (%)	2.59	2.47	2.45	2.37	2.55	2.52
Poor (%)	44.22	42.68	44.07	37.26	37.06	38.81
Rich (%)	36.48	36.80	35.86	41.36	42.43	40.35
Average (%)	19.30	20.52	20.08	21.39	20.51	20.84
Panel B: Height-for-Age Z-scores by Age						
Height-for-Age Z-Score	-0.69	-0.75	-0.71	-0.76	-0.77	-0.88
if Age is 0	(1.79)	(1.78)	(1.80)	(1.75)	(1.74)	(1.75)
Height-for-Age Z-Score	-1.85	-1.83	-1.76	-1.88	-1.97	-2.09
if Age is 1	(1.75)	(1.73)	(1.76)	(1.66)	(1.65)	(1.64)
Height-for-Age Z-Score	-1.85	-1.92	-1.92	-2.01	-2.11	-2.11
if Age is 2	(1.69)	(1.78)	(1.72)	(1.58)	(1.55)	(1.57)
Height-for-Age Z-Score	-1.63	-1.60	-1.75	-1.91	-1.89	-2.01
if Age is 3	(1.59)	(1.60)	(1.61)	(1.48)	(1.45)	(1.52)
Height-for-Age Z-Score	-1.41	-1.48	-1.57	-1.69	-1.71	-1.79
if Age is 4	(1.47)	(1.43)	(1.48)	(1.31)	(1.44)	(1.44)
Obs.	8,265	10,498	44,328	8,644	10,736	45,207

Notes: Standard errors in parentheses. Mother's and father's education are in years. The poor are the children living in the households at the bottom two quintiles of the welfare indicator. The rich are the children living in the households at the top two quintiles of the welfare indicator. The average are the children living in the households at the middle quintiles of the welfare indicator.
Data Source: Demographic and health surveys of MEASURE DHS project.

Table 1.2 (continued): Summary statistics of independent and dependent variables for girls

	Muslims			Non-Muslims		
	No. Days of Exposure:			No. Days of Exposure:		
	0	1 to 29	30	0	1 to 29	30
Panel A: Parent's and Household's Characteristics						
Birth Order	3.43	3.41	3.45	3.39	3.36	3.41
	(2.37)	(2.35)	(2.39)	(2.31)	(2.29)	(2.32)
Mother's Years	4.08	4.00	3.96	4.48	4.48	4.44
of Education	(4.89)	(4.81)	(4.85)	(4.46)	(4.59)	(4.41)
Father's Years	5.07	4.98	4.95	6.20	6.18	6.16
of Education	(5.36)	(5.35)	(5.43)	(4.84)	(4.74)	(4.77)
Mother's Age	26.40	26.38	26.42	26.51	26.37	26.43
at Birth	(6.46)	(6.41)	(6.51)	(6.39)	(6.38)	(6.36)
Father's Age	35.47	35.42	35.55	33.40	33.37	33.49
at Birth	(9.88)	(9.90)	(10.13)	(9.41)	(9.63)	(9.52)
Mother's	157.18	157.23	157.41	156.17	156.28	156.28
Height	(7.12)	(7.03)	(7.04)	(7.03)	(6.97)	(6.99)
Urban (%)	35.30	34.65	34.53	26.16	26.93	26.40
Twin (%)	2.81	2.23	2.57	2.11	2.62	2.70
Poor (%)	42.52	43.41	43.59	38.41	38.11	39.34
Rich (%)	37.82	37.64	36.07	41.02	40.53	40.22
Average (%)	19.67	18.95	20.34	20.57	21.36	20.44
Panel B: Height-for-Age Z-scores by Age						
Height-for-Age	-0.54	-0.51	-0.46	-0.52	-0.57	-0.63
Z-Score if Age=0	(1.71)	(1.66)	(1.68)	(1.68)	(1.61)	(1.64)
Height-for-Age	-1.62	-1.55	-1.52	-1.63	-1.68	-1.82
Z-Score if Age=1	(1.68)	(1.71)	(1.70)	(1.62)	(1.58)	(1.54)
Height-for-Age	-1.78	-1.78	-1.75	-1.80	-1.89	-1.97
Z-Score if Age=2	(1.66)	(1.64)	(1.69)	(1.50)	(1.55)	(1.53)
Height-for-Age	-1.64	-1.58	-1.72	-1.81	-1.76	-1.92
Z-Score if Age=3	(1.58)	(1.62)	(1.59)	(1.46)	(1.42)	(1.50)
Height-for-Age	-1.48	-1.46	-1.54	-1.77	-1.74	-1.79
Z-Score if Age=4	(1.45)	(1.46)	(1.46)	(1.37)	(1.37)	(1.38)
Obs.	7,932	10,126	42,560	8,072	10,344	43,658

Notes: Standard errors in parentheses. Mother's and father's education are in years. The poor are the children living in the households at the bottom two quintiles of the welfare indicator. The rich are the children living in the households at the top two quintiles of the welfare indicator. The average are the children living in the households at the middle quintiles of the welfare indicator.
Data Source: Demographic and health surveys of MEASURE DHS project.

Table 1.3: Estimations of the effect of an hour of exposure to Ramadan during entire gestation on height-for-age Z-scores by gender and age

Age	Measure of Exposure	Boys			Girls		
		Muslims	Non-Muslims	All	Muslims	Non-Muslims	All
0	HER279	-3.4e-05	0.0002	-0.0001	-5.5e-05	0.0001	-0.0002
		(0.0001)	(0.0001)	(0.0002)	(0.0001)	(0.0001)	(0.0002)
	Obs.	15,103	15,951	31,054	14,571	15,537	30,108
1	HER279	5.0e-05	-0.0001	0.0002	0.0003**	-0.0002*	0.0004***
		(0.0001)	(0.0001)	(0.0002)	(0.0001)	(0.0001)	(0.0002)
	Obs.	13,575	15,029	28,604	13,007	14,464	27,471
2	HER279	-0.0002	-9.0e-05	-8.5e-05	9.8e-05	-7.7e-05	0.0002
		(0.0001)	(0.0001)	(0.0002)	(0.0001)	(0.0001)	(0.0002)
	Obs.	12,832	13,898	26,730	12,324	13,366	25,690
3	HER279	-0.0003**	7.9e-05	-0.0004**	-0.0001	-9.4e-05	-2.5e-05
		(0.0001)	(0.0001)	(0.0002)	(0.0001)	(0.0001)	(0.0002)
	Obs.	11,222	10,322	21,544	10,910	9,894	20,804
4	HER279	-0.0003**	1.8e-07	-0.0003*	0.0001	-4.5e-05	0.0001
		(0.0001)	(0.0001)	(0.0002)	(0.0001)	(0.0001)	(0.0002)
	Obs.	10,359	9,387	19,746	9,806	8,813	18,619

Notes: HER279 is hours of exposure to Ramadan during the entirety of gestation, which is assumed to be 279 days. The coefficients show the effect of an hour of exposure to Ramadan. The control variables are age in days, year of birth, month of birth, birth order, a variable that indicate twin birth, urban/rural indicator, an indicator of province or state of residence, parents' age at child's birth, parent's education, mother's height, and household's wealth indicator. The regressions are set such that the coefficients under All columns be equal to the difference of the corresponding coefficients under columns Muslim and Non-Muslim (any discrepancy is caused by rounding the numbers to four decimals). Standard errors in parentheses. *** significant at the 1 percent level; ** significant at the 5 percent level; * significant at the 10 percent level.
Data Source: Demographic and health surveys of MEASURE DHS project.

Table 1.4: Estimations of the effect of an hour of exposure to Ramadan during trimesters of gestation on height-for-age Z-scores by gender and age

Age	Measure of Exposure	Boys Muslims	Boys Non-Muslims	Boys All	Girls Muslims	Girls Non-Muslims	Girls All
0	HERt3	-0.0001	5.9e-05	-0.0002	-0.0002	0.0002*	-0.0004**
		(0.0001)	(0.0001)	(0.0002)	(0.0001)	(0.0001)	(0.0002)
	HERt2	-0.0001	0.0002	-0.0003	-0.0002	0.0003**	-0.0005**
		(0.0002)	(0.0001)	(0.0002)	(0.0001)	(0.0001)	(0.0002)
	HERt1	8.2e-05	0.0001	-6.1e-05	0.0002	1.2e-05	0.0002
		(0.0001)	(0.0001)	(0.0002)	(0.0001)	(0.0001)	(0.0002)
	Obs.	15,103	15,951	31,054	14,571	15,537	30,108
1	HERt3	-0.0001	-8.4e-05	-3.2e-05	0.0002	-0.0002	0.0004**
		(0.0001)	(0.0001)	(0.0002)	(0.0001)	(0.0001)	(0.0002)
	HERt2	-2.6e-06	-3.6e-05	3.3e-05	0.0003*	-0.0001	0.0004*
		(0.0002)	(0.0001)	(0.0002)	(0.0002)	(0.0001)	(0.0002)
	HERt1	0.0002*	-0.0002	0.0004**	0.0003*	-0.0002*	0.0005***
		(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0002)
	Obs.	13,575	15,029	28,604	13,007	14,464	27,471
2	HERt3	-0.0003*	-6.8e-05	-0.0002	-2.1e-05	-8.0e-05	5.9e-05
		(0.0002)	(0.0001)	(0.0002)	(0.0001)	(0.0001)	(0.0001)
	HERt2	-7.9e-05	-8.9e-05	10.0e-06	0.0001	-9.7e-05	0.0002
		(0.0001)	(0.0001)	(0.0002)	(0.0001)	(0.0001)	(0.0002)
	HERt1	-0.0001	-0.0001	-1.0e-05	0.0002	-6.1e-05	0.0003
		(0.0001)	(0.0001)	(0.0002)	(0.0001)	(0.0001)	(0.0002)
	Obs.	12,832	13,898	26,730	12,324	13,366	25,690
3	HERt3	-0.0005***	0.0002	-0.0006***	-0.0002	6.8e-05	-0.0003
		(0.0002)	(0.0002)	(0.0001)	(0.0002)	(0.0001)	(0.0002)
	HERt2	-7.6e-05	7.5e-05	-0.0002	-2.3e-05	-0.0002	0.0002
		(0.0002)	(0.0002)	(0.0001)	(0.0002)	(0.0002)	(0.0002)
	HERt1	-0.0003*	-1.2e-05	-0.0003*	-7.1e-05	-0.0002	0.0001
		(0.0002)	(0.0001)	(0.0001)	(0.0002)	(0.0001)	(0.0002)
	Obs.	11,222	10,322	21,544	10,910	9,894	20,804
4	HERt3	-0.0003*	6.01e-05	-0.0003***	0.0001	2.55e-05	7.7e-05
		(0.0001)	(0.0001)	(6.6e-05)	(0.0001)	(0.0001)	(0.0002)
	HERt2	-0.0004**	4.13e-05	-0.0004***	0.0001	3.8e-06	0.0001
		(0.0001)	(0.0001)	(9.5e-05)	(0.0001)	(0.0001)	(0.0002)
	HERt1	-0.0003**	-8.0e-05	-0.0002	9.4e-05	-0.0001	0.002
		(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0002)
	Obs.	10,359	9,387	19,746	9,806	8,813	18,619

Notes: HERt1, HERt2, and HERt3 are hours of exposure to Ramadan during the 1st, 2nd, and 3rd trimesters of gestation, respectively. The coefficients show the effect of an hour of exposure to Ramadan in each trimester. The control variables are age in days, year of birth, month of birth, birth order, a variable that indicate twin birth, urban/rural indicator, an indicator of province or state of residence, parents' age at child's birth, parent's education, mother's height, and household's wealth indicator. The regressions are set such that the coefficients under All columns be equal to the difference of the corresponding coefficients under columns Muslim and Non-Muslim (any discrepancy is caused by rounding the numbers to four decimals). Standard errors in parentheses. *** significant at the 1 percent level; ** significant at the 5 percent level; * significant at the 10 percent level.
Data Source: Demographic and health surveys of MEASURE DHS project.

Table 1.5: Estimations of the effect of an hour of exposure to Ramadan during months of gestation on height-for-age Z-scores of boys by age

	Age=0		Age=1		Age=2		Age=3		Age=4	
	Muslims	Non-Muslims	Muslims	Non-Muslims	Muslims	Non-Muslims	Muslims	Non-Muslims	Muslims	Non-Muslims
HERm9	5.3e-05	-6.5e-05	-6.4e-05	-0.0002	-0.0003	9.3e-05	-0.0003*	5.9e-05	-0.0004*	2.9e-06
	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0001)	(0.0002)	(0.0002)	(0.0002)
HERm8	-0.0002	0.0003	-0.0002	-0.0002	-6.3e-05	-2.9e-05	-0.0005***	-0.0001	-0.0004	0.0002
	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0001)	(0.0002)	(0.0002)	(0.0002)
HERm7	7.5e-05	-0.0001	-0.0003	0.0002	-0.0002	-1.5e-05	-0.0004**	0.0002	-0.0007***	-2.3e-05
	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0001)	(0.0002)	(0.0002)	(0.0002)
HERm6	-0.0001	0.0003	-0.0002	-4.1e-05	9.4e-05	0.0002	-0.0004*	-7.8e-05	-0.0006**	0.0002
	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)
HERm5	-4.8e-05	-5.7e-05	1.5e-05	-0.0001	-8.4e-06	-7.3e-05	0.0004***	4.1e-05	-0.0006***	-2.8e-05
	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0003)	(0.0002)	(9.3e-05)	(0.0002)	(0.0002)	(0.0002)
HERm4	6.8e-05	0.0003	-8.2e-05	0.0001	-6.5e-05	-1.4e-05	-0.0002	-0.0001	-0.0006**	-1.8e-05
	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0003)	(0.0002)	(0.0001)	(0.0002)	(0.0002)	(0.0002)
HERm3	0.0004	0.0001	0.0002	-0.0002	-2.8e-05	3.0e-05	5.5e-05	-0.0002	-0.0007***	-0.0002
	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0001)	(0.0002)	(0.0002)	(0.0002)
HERm2	0.0002	0.0003	0.0003	-0.0001	0.0001	0.0003	-0.0002	-0.0003	-0.0004*	-3.1e-05
	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0001)	(0.0002)	(0.0002)	(0.0002)
HERm1	-0.0002	-0.0001	3.6e-05	-9.0e-05	-0.0003	-0.0004**	-0.0005**	0.0001	-0.0006**	-4.3e-05
	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)
HERm0	0.0002	4.0e-05	-0.0002	5.1e-06	0.0002	0.0003	0.0001	-0.0003	-0.0005**	4.6e-05
	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0003)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)
Obs.	15,103	15,951	13,575	15,029	12,832	13,898	11,222	10,322	10,359	9,387

Notes: HERm0, HERm1, HERm2, ..., and HERm9 are hours of exposure to Ramadan during the month before conception, 1st, 2nd, ..., and 9th months of gestation, respectively. The coefficients show the effect of an hour of exposure to Ramadan in each month. The control variables are age in days, year of birth, month of birth, birth order, a variable that indicate twin birth, urban/rural indicator, an indicator of province or state of residence, parents' age at child's birth, parent's education, mother's height, and household's wealth indicator. The results of regressions with all Muslim and non-Muslim observations are not reported to save space. But, the coefficient of the interaction term in such regressions can be found by computing the difference of the corresponding coefficients under columns Muslim and Non-Muslim. Standard errors in parentheses. *** significant at the 1 percent level; ** significant at the 5 percent level; * significant at the 10 percent level.

Data Source: Demographic and health surveys of MEASURE DHS project.

Table 1.6: Estimations of the effect of an hour of exposure to Ramadan during months of gestation on height-for-age Z-scores of girls by age

	Age=0		Age=1		Age=2		Age=3		Age=4	
	Muslims	Non-Muslims	Muslims	Non-Muslims	Muslims	Non-Muslims	Muslims	Non-Muslims	Muslims	Non-Muslims
HERm9	-0.0004*	-5.9e-05	0.0005**	-0.0003	-0.0003	-0.0002	0.0001	-0.0002	-0.0004*	-3.2e-05
	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0003)	(0.0002)	(0.0002)	(0.0002)
HERm8	4.1e-05	0.0002	-4.3e-05	-1.3e-05	1.6e-05	-0.0001	-0.0004*	0.0002	-5.5e-05	-2.1e-05
	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)
HERm7	-0.0005**	0.0002	0.0004	-0.0002	-0.0003	0.0001	-0.0003	-0.0002	-5.3e-05	-0.0001
	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)
HERm6	-0.0005**	0.0004**	0.0002	-0.0002	3.5e-05	-8.9e-05	0.0003	-0.0003	-0.0001	-0.0002
	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0003)	(0.0002)	(0.0002)	(0.0002)
HERm5	-0.0005**	-1.0e-05	0.0005*	-0.0002	0.0003	0.0001	-0.0003	-0.0002	-0.0003	-0.0002
	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0003)	(0.0002)	(0.0002)	(0.0002)
HERm4	0.0002	0.0002	0.0001	-4.5e-05	-0.0004	-0.0003	-9.7e-05	-0.0004*	0.0001	0.0004
	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0003)	(0.0002)	(0.0002)	(0.0002)
HERm3	5.9e-05	-4.2e-06	0.0004*	-0.0002	0.0003	8.0e-05	-0.0002	-0.0001	-0.0001	5.1e-05
	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)
HERm2	-5.4e-06	-0.0002	0.0004	-0.0004*	-9.4e-05	-0.0002	-0.0001	-0.0007***	-0.0003	-0.0003
	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)
HERm1	0.0002	-4.4e-05	0.0001	-4.2e-05	3.2e-05	-3.6e-07	5.3e-05	-0.0002	5.0e-06	-0.0003
	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)
HERm0	-0.0002	-0.0003	3.4e-05	-4.2e-05	-0.0004*	-2.9e-05	-3.0e-05	-0.0003	-0.0006***	-0.0002
	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)
Obs.	14,571	15,537	13,007	14,464	12,324	13,366	10,910	9,894	9,806	8,813

Notes: HERm0, HERm1, HERm2, ..., and HERm9 are hours of exposure to Ramadan during the month before conception, 1st, 2nd, ..., and 9th months of gestation, respectively. The coefficients show the effect of an hour of exposure to Ramadan in each month. The control variables are age in days, year of birth, month of birth, birth order, a variable that indicate twin birth, urban/rural indicator, an indicator of province or state of residence, parents' age at child's birth, parent's education, mother's height, and household's wealth indicator. The results of regressions with all Muslim and non-Muslim observations are not reported to save space. But, the coefficient of the interaction term in such regressions can be found by computing the difference of the corresponding coefficients under columns Muslim and Non-Muslim. Standard errors in parentheses. *** significant at the 1 percent level; ** significant at the 5 percent level; * significant at the 10 percent level.

Data Source: Demographic and health surveys of MEASURE DHS project.

Table 1.7: Estimations of the effect of an hour and a day of exposure to Ramadan during entirety and trimesters of gestation on children's mothers' height-for-age Z-scores

	Hours of Exposure			Days of Exposure		
	Muslims	Non-Muslims	All	Muslims	Non-Muslims	All
Entire Gestation	8.5e-05	3.3e-05	5.2e-05	0.0009	0.0003**	0.0006
	(3.9e-05)	(8.0e-06)	(4.7e-05)	(0.0004)	(1.3e-05)	(0.0004)
Obs.	65,507	68,818	134,325	65,507	68,818	134,325
3rd Trimester	3.5e-05	4.1e-05	-5.8e-06	0.0003	0.0004	-0.0001
	(5.9e-05)	(3.0e-05)	(8.9e-05)	(0.0007)	(0.0003)	(0.0010)
2nd Trimester	9.6e-05	5.7e-05	3.9e-05	0.0011	0.0006**	0.0004
	(3.2e-05)	(1.0e-05)	(4.2e-05)	(0.0003)	(3.1e-05)	(0.0003)
1st Trimester	0.0001	2.0e-05	0.0001*	0.0015	0.00020	0.0013***
	(2.3e-05)	(1.2e-05)	(1.1e-05)	(0.0003)	(0.0003)	(5.5e-06)
Obs.	65,507	68,818	134,325	65,507	68,818	134,325

Notes: Effect of exposure to Ramadan in utero on children's mothers' height is examined to check if no late childhood height effect for girls (demonstrated in previous tables) translates to adulthood. The coefficients under "Hour of Exposure"show the effect of an hour of exposure to Ramadan during entirety and trimesters of gestation. However, the coefficients under "Days of Exposure" show the effect of a day of exposure to Ramadan during entirety and trimesters of gestation. Mother birth day is no available. Therefore, the exposure measures are computed assuming that all mothers are born at the 15th of their birth month (the results will not change if any day from 10 to 20 is chosen). The control variables are age in days, year of birth, month of birth, urban/rural indicator, an indicator of province or state of residence, and household's wealth indicator. The regressions are set such that the coefficients under All columns be equal to the difference of the corresponding coefficients under columns Muslim and Non-Muslim (any discrepancy is caused by rounding the numbers to four decimals). Standard errors in parentheses. *** significant at the 1 percent level; ** significant at the 5 percent level; * significant at the 10 percent level.
Data Source: Demographic and health surveys of MEASURE DHS project.

Table 1.8: Age-specific estimations of the effect of exposure to Ramadan by 1-10, 11-20, and 21-30 days during entire gestation on boys' height-for-age Z-scores

	Muslims	Non-Muslims	All	Muslims	Non-Muslims	All
		Age=0:			Age=3:	
1-10 Days	-0.116*	0.0969	-0.213**	-0.0737	-0.0476	-0.0261
	(0.0689)	(0.0632)	(0.0933)	(0.0282)	(0.0697)	(0.0176)
11-20 Days	-0.0201	0.0592	-0.0793	-0.0768*	0.0088	-0.0856
	(0.0686)	(0.0643)	(0.0939)	(0.0111)	(0.0696)	(0.0376)
21-30 Days	-0.0433	0.0569	-0.100	-0.123***	0.0282	-0.151**
	(0.0452)	(0.0421)	(0.0617)	(0.0017)	(0.0471)	(0.0028)
Obs.	15,103	15,951	31,054	11,222	10,322	21,544
		Age=1:			Age=4:	
1-10 Days	-0.0066	0.0141	-0.0207	-0.110	0.0276	-0.138
	(0.0697)	(0.0398)	(0.0933)	(0.0675)	(0.0696)	(0.0972)
11-20 Days	-0.0157	-0.113	0.0973	-0.193***	-0.0061	-0.187**
	(0.0704)	(0.0646)	(0.0946)	(0.0669)	(0.0667)	(0.0946)
21-30 Days	0.0192	-0.0425	0.0617	-0.132***	-0.0070	-0.125*
	(0.0457)	(0.0283)	(0.0615)	(0.0453)	(0.0470)	(0.0654)
Obs.	13,575	15,029	28,604	10,359	9,387	19,746
		Age=2:				
1-10 Days	0.0121	0.0016	0.0105			
	(0.0719)	(0.0491)	(0.0950)			
11-20 Days	-0.0453	-0.136	0.0911			
	(0.0720)	(0.0883)	(0.0946)			
21-30 Days	-0.0497	-0.0499	0.00013			
	(0.0461)	(0.0415)	(0.0613)			
Obs.	12,832	13,898	26,730			

Notes: These tests are intended to examine how changing the intensity of exposure to Ramadan impacts the results. The exposure measure in these regressions is an index variable that takes four values: 0 if there is 0 day of exposure, 1 if there is/are 1 to 10 day(s) of exposure, 2 if there are 11 to 20 days of exposure, 3 if there are 21 to 30 days of exposure. The estimated coefficients of the index variable are presented in this table. The coefficients show the marginal effects of days of exposure to Ramadan at the ranges with respect to when there is no exposure. The control variables are age in days, year of birth, month of birth, birth order, a variable that indicate twin birth, urban/rural indicator, an indicator of province or state of residence, parents' age at child's birth, parent's education, mother's height, and household's wealth indicator. The regressions are set such that the coefficients under All columns be equal to the difference of the corresponding coefficients under columns Muslim and Non-Muslim (any discrepancy is caused by rounding the numbers to four decimals). Standard errors in parentheses. *** significant at the 1 percent level; ** significant at the 5 percent level; * significant at the 10 percent level.

Data Source: Demographic and health surveys of MEASURE DHS project.

Table 1.9: Estimations of the effect of any exposure of male children and their mothers to Ramadan during entire gestation on male children's height-for-age Z-scores by age (only Muslims are included)

	Boys	Boys & Mothers	Boys & Mothers & Interaction	Boys	Boys & Mothers	Boys & Mothers & Interaction
		Age=0:			Age=3:	
ER279	-0.0546	-0.0545	0.0189	-0.113**	-0.113**	-0.195
	(0.0439)	(0.0440)	(0.124)	(0.0462)	(0.0462)	(0.121)
ER279m		0.00478	0.0776		0.0274	-0.0544
		(0.0423)	(0.122)		(0.0424)	(0.120)
ER279×ER279m			-0.0826			0.0934
			(0.130)			(0.128)
Obs.	14,977	14,977	14,977	11,102	11,102	11,102
		Age=1:			Age=4:	
ER279	0.00703	0.00707	-0.0626	-0.133***	-0.132***	-0.150
	(0.0444)	(0.0444)	(0.119)	(0.0436)	(0.0436)	(0.123)
ER279m		-0.0273	-0.0964		0.0427	0.0255
		(0.0423)	(0.118)		(0.0397)	(0.121)
ER279×ER279m			0.0793			0.0193
			(0.126)			(0.128)
Obs.	13,451	13,451	13,451	10,237	10,237	10,237
		Age=2:				
ER279	-0.0434	-0.0437	-0.0630			
	(0.0448)	(0.0448)	(0.122)			
ER279m		0.0278	0.00892			
		(0.0446)	(0.119)			
ER279×ER279m			0.0219			
			(0.128)			
Obs.	12,708	12,708	12,708			

Notes: These tests are designed to explore transmission of Ramadan height effect from mothers to male children. ER279 is the index of boys' exposure to Ramadan during the entire gestation, which takes value 1 if there has been any exposure and 0 otherwise. ER279m is the index of mothers' exposure to Ramadan during the entire gestation, which takes value 1 if there has been any exposure and 0 otherwise. It is assumed that all mothers are born at the 15 of their birth moth. Initially, for the sake of comparison, only boys' exposure to Ramadan (measured by ER279) is plugged into the regressions and the estimated coefficients are reported under the column"Boys". The coefficients show the average height effect of exposure to Ramadan on Muslim boys by age. Then, both boys' and mothers' exposure to Ramadan (measured by ER279 and ER279m, respectively) are plugged into the regressions and the estimated coefficients are reported under the column"Boys & Mothers". Finally, the interaction variable of boys' and mothers' exposure (ER279×ER279m) is added to the regressions and the estimated coefficients are reported under the column"Boys & Mothers & Interaction". The control variables are age in days, year of birth, month of birth, birth order, a variable that indicate twin birth, urban/rural indicator, an indicator of province or state of residence, parents' age at child's birth, parent's education, mother's height, and household's wealth indicator. Only Muslim boys and their mothers are examined. Standard errors in parentheses. *** significant at the 1 percent level; ** significant at the 5 percent level; * significant at the 10 percent level.
Data Source: Demographic and health surveys of MEASURE DHS project.

Table 1.10: Estimations of the effect of any exposure of male children and their mothers to Ramadan during trimesters of gestation on male children's height-for-age Z-scores by age (only Muslims are included)

	Boys	Boys & Mothers	Boys & Mothers & Interaction	Boys	Boys & Mothers	Boys & Mothers & Interaction	Boys	Boys & Mothers	Boys & Mothers & Interaction
	Age=0:			Age=1:			Age=2:		
ERt3	-0.0188	-0.0202	-0.0303	-0.0448	-0.0447	-0.0515	-0.0408	-0.0410	-0.0386
	(0.0389)	(0.0389)	(0.0447)	(0.0388)	(0.0388)	(0.0447)	(0.0402)	(0.0402)	(0.0464)
ERt2	-0.0045	-0.0053	-0.0231	-0.0054	-0.0055	0.0189	0.0334	0.0340	0.0448
	(0.0375)	(0.0375)	(0.0431)	(0.0375)	(0.0375)	(0.0431)	(0.0382)	(0.0382)	(0.0442)
ERt1	0.0148	0.0140	0.0238	0.0643	0.0637	0.0425	0.0034	0.0032	-0.0101
	(0.0387)	(0.0387)	(0.0446)	(0.0394)	(0.0394)	(0.0450)	(0.0399)	(0.0399)	(0.0461)
ERt3m		0.0450	0.0341		-0.0387	-0.0461		-0.0764**	-0.0736*
		(0.0361)	(0.0424)		(0.0363)	(0.0427)		(0.0374)	(0.0437)
ERt2m		-0.00801	-0.0252		-0.0079	0.0154		-0.0521	-0.0419
		(0.0312)	(0.0374)		(0.0314)	(0.0378)		(0.0324)	(0.0390)
ERt1m		-0.0094	9.9e-05		-0.0727**	-0.0944**		-0.0212	-0.0341
		(0.0364)	(0.0424)		(0.0366)	(0.0426)		(0.0379)	(0.0442)
ERt3 × ERt3m			0.0313			0.0191			-0.0078
			(0.0636)			(0.0640)			(0.0659)
ERt2 × ERt2m			0.0515			-0.0692			-0.0302
			(0.0619)			(0.0622)			(0.0638)
ERt1 × ERt1m			-0.0275			0.0641			0.0380
			(0.0643)			(0.0649)			(0.0659)
Obs.	14,977	14,977	14,977	13,451	13,451	13,451	12,708	12,708	12,708

	Boys	Boys & Mothers	Boys & Mothers & Interaction	Boys	Boys & Mothers	Boys & Mothers & Interaction
	Age=3:			Age=4:		
ERt3	-0.142***	-0.142***	-0.149***	-0.0601	-0.0590	-0.0707
	(0.0400)	(0.0400)	(0.0459)	(0.0374)	(0.0374)	(0.0431)
ERt2	0.0104	0.0103	-0.0031	-0.0820**	-0.0808**	-0.0886**
	(0.0385)	(0.0385)	(0.0440)	(0.0355)	(0.0355)	(0.0406)
ERt1	-0.107***	-0.107***	-0.0881*	-0.0874**	-0.0863**	-0.124***
	(0.0400)	(0.0400)	(0.0455)	(0.0376)	(0.0376)	(0.0430)
ERt3m		0.0156	0.00840		0.0893***	0.0783**
		(0.0364)	(0.0426)		(0.0340)	(0.0397)
ERt2m		0.0378	0.0249		0.0235	0.0147
		(0.0316)	(0.0384)		(0.0294)	(0.0355)
ERt1m		0.0039	0.0229		0.0298	-0.0087
		(0.0367)	(0.0429)		(0.0343)	(0.0403)
ERt3 × ERt3m			0.0196			0.0304
			(0.0646)			(0.0598)
ERt2 × ERt2m			0.0364			0.0243
			(0.0616)			(0.0581)
ERt1 × ERt1m			-0.0554			0.109*
			(0.0649)			(0.0599)
Obs.	11,102	11,102	11,102	10,237	10,237	10,237

Notes:
ERt1: 0/1 exposure index at the 1st trimester of gestation (boys)
ERt2: 0/1 exposure index at the 2nd trimester of gestation (boys)
ERt3: 0/1 exposure index at the 3rd trimester of gestation (boys)
ERt1m: 0/1 exposure index at the 1st trimester of gestation (mothers)
ERt2m: 0/1 exposure index at the 2nd trimester of gestation (mothers)
ERt3m: 0/1 exposure index at the 3rd trimester of gestation (mothers)
For more explanation, please see the notes of Table 1.12.

Data Source: Demographic and health surveys of MEASURE DHS project.

Table 1.11: Dividing observations along the ranges of latitude by gender, religion, and age

Panel A: Boys										
Latitude	Number of Muslims at Age:					Number of Non-Muslims at Age:				
Range	0	1	2	3	4	0	1	2	3	4
30°N plus	3,196	3,153	3,012	2,674	2,525	867	887	870	418	416
25°N–30°N	1,707	1,599	1,649	1,516	1,437	1,543	1,426	1,441	712	630
20°N–25°N	2,092	1,893	1,887	1,923	1,747	1,518	1,428	1,347	789	733
15°N–20°N	601	486	481	338	298	591	566	563	230	260
10°N–15°N	4,718	3,800	3,501	2,848	2,538	1,851	1,696	1,674	1,270	1,153
5°N–10°N	1,389	1,196	1,142	960	860	3,346	3,089	2,811	2,413	2,178
5°S–5°N	521	453	406	350	342	2,961	2,753	2,557	1,977	1,846
5°S plus	878	793	754	614	613	3,273	3,186	2,635	2,514	2,171

Panel B: Girls										
Latitude	Number of Muslims at Age:					Number of Non-Muslims at Age:				
Range	0	1	2	3	4	0	1	2	3	4
30°N plus	3,096	2,994	2,910	2,613	2,375	757	711	710	307	275
25°N–30°N	1,639	1,477	1,485	1,416	1,346	1,460	1,314	1,250	648	575
20°N–25°N	1,960	1,932	1,851	1,789	1,645	1,387	1,270	1,284	722	690
15°N–20°N	543	505	425	327	287	500	553	480	219	199
10°N–15°N	4,601	3,764	3,429	2,832	2,428	1,775	1,647	1,573	1,204	1,117
5°N–10°N	1,356	1,074	1,038	972	830	3,481	3,051	2,772	2,358	2,006
5°S–5°N	469	446	424	343	301	2,923	2,787	2,564	1,925	1,760
5°S plus	907	815	762	618	595	3,255	3,132	2,733	2,510	2,191

Notes: Observations are divided along 8 latitude ranges: 5°S plus, 5°S–5°N, 5°N–10°N, 10°N–15°N, 15°N–20°N, 20°N–25°N, 25°N–30°N, 30°N plus. The latitude range "5°S plus"indicates the locations at latitude 5 degree or more in the southern hemisphere; The latitude range "5°S-5°N"indicates the locations between latitude 5 degree in the southern hemisphere and latitude 5 degree in the northern hemisphere; The latitude range 5°N-10°N indicates the locations between latitudes 5 and 10 degrees in the northern hemisphere; ...; The latitude range "30°N plus"indicates the locations at latitude 30 degree or more in the northern hemisphere.
Data Source: Demographic and health surveys of MEASURE DHS project.

Table 1.12: Estimations of the effect of latitude on height-for-age Z-scores of exposed Muslim children by age

Latitude	Boys					Girls				
Range	Age=0	Age=1	Age=2	Age=3	Age=4	Age=0	Age=1	Age=2	Age=3	Age=4
L8 (30°N plus)	-0.00961	0.0143	0.00171	-0.0129	0.00390	-0.00160	-0.0115	-0.00189	0.00281	-0.0125
	(0.00936)	(0.00978)	(0.00929)	(0.0104)	(0.00979)	(0.00904)	(0.00911)	(0.00942)	(0.0108)	(0.0104)
L7 (25°N–30°N)	-0.00541	0.00504	-0.00724	-0.0134	-0.00636	0.00385	-0.00605	0.00110	-0.00301	0.000620
	(0.00912)	(0.00960)	(0.00916)	(0.00958)	(0.00928)	(0.00850)	(0.00871)	(0.00899)	(0.00982)	(0.00944)
L6 (20°N–25°N)	-0.00864	0.0130	-0.00513	-0.00511	-0.000982	-0.00441	-0.00342	-0.00116	-0.00542	0.000480
	(0.00895)	(0.00950)	(0.00913)	(0.00935)	(0.00895)	(0.00843)	(0.00860)	(0.00871)	(0.00955)	(0.00905)
L5 (15°N–20°N)	0.000160	0.0155	-0.00754	-0.0175	-0.00460	-0.00631	-0.0145	-0.00324	-0.0156	-0.00601
	(0.0114)	(0.0119)	(0.0115)	(0.0131)	(0.0129)	(0.0108)	(0.0108)	(0.0113)	(0.0139)	(0.0131)
L4 (10°N–15°N)	-0.00385	-0.00232	0.00155	-0.00430	0.00221	-0.00983	-0.0155*	-0.00907	-0.0117	0.00218
	(0.00853)	(0.00920)	(0.00880)	(0.00883)	(0.00862)	(0.00801)	(0.00824)	(0.00841)	(0.00894)	(0.00873)
L3 (5°N–10°N)	-0.00999	0.00810	0.00215	-0.00604	0.0138	0.00482	-0.00328	0.00431	-0.0128	-0.00510
	(0.00892)	(0.00962)	(0.00914)	(0.00923)	(0.00906)	(0.00836)	(0.00874)	(0.00901)	(0.00923)	(0.00926)
L1 (5°S plus)	-0.0118	0.00446	0.00491	-0.00577	0.00198	0.00593	-0.00426	-0.00391	-0.00489	-0.00126
	(0.00941)	(0.00992)	(0.00950)	(0.00953)	(0.00928)	(0.00882)	(0.00896)	(0.00926)	(0.00964)	(0.00929)
Obs.	31,054	28,604	26,730	21,544	19,746	30,108	27,471	25,690	20,804	18,619

Notes: These test are conducted to investigate how variations in latitude changes the differential effect of exposure to Ramadan. The values are the estimations of the coefficients of the variables that contain the interaction of each latitude dummy by days of exposure to Ramadan during entire gestation and religion. The latitude dummies are defined as L1 (5°S plus), L3 (5°N–10°N), L4 (10°N–15°N), L5 (15°N–20°N), L6 (20°N–25°N), L7 (25°N–30°N), and L8 (30°N plus) for the corresponding latitude ranges. The latitude dummy L2 (5°S–5°N) is dropped as the reference latitude range. A separate regression is estimated for boys at each age. Similarly, a separate regression is estimated for girls at each age. Standard errors in parentheses. *** significant at the 1 percent level; ** significant at the 5 percent level; * significant at the 10 percent level.

Data Source: Demographic and health surveys of MEASURE DHS project.

CHAPTER 2

WELFARE IMPLICATIONS OF A BIG BANG APPROACH TO REFORM ENERGY AND FOOD SUBSIDIES

2.1 Introduction

Price subsidies, especially on fuel and energy carriers, are the most unequally distributed government transfers to the private sector.[1] The magnitude of the unequal distribution used to be particularly noticeable in Iran, where energy carriers were massively underpriced. Highly skewed distribution of gasoline subsides is a striking example. In 2010, the cash equivalent of the gasoline price subsidies paid to an average urban Iranian household in the top income decile was about 30 times more than that paid to an average urban Iranian household in the bottom income decile simply because the major consumers of gasoline are the rich. Set aside the distributive drawback of price subsidies, wasting energy and neglecting energy conservation in constructions, transportation, and residential uses are induced by underpriced fuels beside the environmental and health damages of the resulted pollution. Government's fiscal imbalance from handling the massive price subsidies should also be added to the lists of harms. Fiscal concerns may seem irrelevant in the case of Iran with exceptional oil revenues, which may make it redundant to levy distortionary taxes to finance the price subsidy scheme, but it has transpired that the demand for the incredibly underpriced energy has been exponentially increasing devouring a constantly growing share of the country's oil revenues.

To address the described problems, the Iranian government undertook a reform to eliminate the energy and food price subsidies on December 18, 2010. In an abrupt elimination of energy carriers' and foods' price subsidies, the prices of the most of the subsidized energy and food items were elevated by more than hundred percent. For the most important energy sources of

[1] This is a joint work with Prof. Firouz Gahvari.

households, namely natural gas, gasoline, and electricity, prices were raised by above 500%, 600%, and 60%, respectively. Knowing that the poor could be crushed by such a monstrous end, government conducted a parallel rebate scheme in which households received government cash transfers in a uniform manner according to the number of households' members. Analyzing the welfare and fiscal consequences of this enormous policy change is the subject of this study. The rich and long-running Iranian household surveys create a rare opportunity to embark welfare and fiscal analyses of this *Big Bang* approach to reform price subsidy structures in a developing country.

For these purposes, first the subsidy system in Iran, debates on its reform, and how the reform was applied are described to create the pertinent institutional background. A review of the literature that have examined changes in price subsidies is presented next. The review reveals that the theoretical framework to assess non-marginal price changes is underdeveloped. Therefore, the structure that is designed to examine marginal price changes is inevitably adopted for the case in hand. The model and the estimation strategy are introduced next. The selected theoretical model employs Quadratic Almost Ideal Demand System (QUAIDS), which is suitable to assess consumer behavior that illustrates nonlinearity in the Engel curves. Then the data, household budget surveys, price indices and any other piece of information that is used, are described. This study focuses on urban households because of the lack of price data in rural areas that constitute less than 30% of the population. The empirical Engel curves are drawn to justify using the QUAIDS model, then the estimation results and elasticities are presented. While cross-price compensated elasticities and income elasticities create the ground to run initial welfare analyses, the more comprehensive welfare analyses are conducted in the next sections.

To commence fiscal and welfare analyses of the subsidy reform, the results of the estimations are used to evaluate the change in the cash equivalent of government transfers to households induced by the reform. The results show that while the size the net transfers to an average urban household, including cash equivalent of price subsidies and the post-reform rebates, is shrunk, the lower income half of the population are expected to undergo growth in net transfers. Even without launching more precise welfare evaluations, this crude measure indicates improvement in targeting. The change in the transfers to households is just the flip side of the change in government's fiscal condition. Thus, it is expected that the government have positive balance. Details of fiscal consequences of the subsidy reform are thus opened up in the followed section. Notably, it is illustrated that the expected increase in the government's foreign revenues from selling the decreased domestic energy consumption, caused by the elevated domestic prices, does potentially shape the biggest source of funding the rebates. In the next section, a relevant welfare analysis is conducted using the concept of equivalent variation. The derived results defy the implications of the findings about the change in monetary transfers and indicate that only the top 30% of the urban society do not better off by the reform. In the next section, all of these calculations are repeated for the case in which the government is facing trade barriers and cannot sell realize its foreign revenues.

It should be noted that this study does not consider the effects of the subsidy reform on producer prices. This *per se* needs a separate complementary research that considers the share of domestically produced goods in total consumption and how energy-intensive their production technology are. Thus, the results of this study should be considered as upper bound of the true effects.

2.2 Subsidy system in Iran and 2009 Subsidy Reform Act

Energy and necessary foods have been under-priced in the last decades in Iran. Under-pricing, in fact, has been strikingly more severe for energy carriers and enforced with the government that is the sole supplier of energy and has the ultimate market power in the Iranian energy market. Iran actually obtained the second lowest rank among 168 countries in terms of pump price for gasoline and diesel oil among 168 countries, after Venezuela, in 2010.[2] The specifics are more illustrative in this regard. A liter of gasoline priced at $0.097 in 2010 in Iran that was about 13 times cheaper than the world average of $1.234 and about 11 times cheaper than the neighboring countries' average. Diesel oil is even cheaper relatively; it is about 68 times cheaper than the world average and 55 times cheaper than the neighboring countries'

[2] Pump price for gasoline and diesel oil across the world, expressed in terms of US$ per liter, are make available by the World Bank in http://databank.worldbank.org/ddp/

average.

While Iran's enormous oil revenues allow the Iranian government to distribute the public largesse, there have been long-lasting debates on how to manage eliminating the indirect price subsidies and moving toward better-targeted direct subsidies. The administrations in charge in 1990s and early 2000s believed in a step-wise gradual procedure of elimination of the prices subsidies such that energy prices were increased by about 20% at the first day of April each year. This policy was discarded by the new administration in 2005 and the prices of energy and necessary foods were kept unchanged for the second half of 2000s. Extensive fiscal costs of this policy finally persuaded the administration to compensate the dramatic lift in its expenditures and consider fundamental reform price subsidy policies. Pursuing the new approach finally led to 2009 Subsidy Reform Act.

The 2009 Subsidy Reform Act obliges government to gradually eliminate the subsidies on the prices of energy carriers, piped water, wheat, rice, vegetable oil, milk, sugar, post services, and aerial and railroad transportation until the end of country's Fifth Five-Year Development Plan, which spans from 2011 to 2015. More specifically, through a time period of five years, the prices of oil products were mandated to reach the 90% of their Persian Gulf FOB prices[3]. Similarly, it was mandated to raise the price of natural gas to 75% of its average export price, the price of electricity to its production costs, and the price of piped water to its delivery costs. All the elevated prices should include transportation costs, distribution costs, taxes, and tolls. The government, then, was allowed to spent (1) up to 50% of the raised revenues on direct cash transfers and social security purposes to households; (2) 30% of it on supporting production sector via promoting energy-efficient technologies, developing public transportation, encouraging non-oil export, extending information technology, and compensating the losses of utility companies; (3) up to 20% it on compensating the expected declines in the it development expenditures.

Execution of the act was postponed several times until the 19th of December 2010, when its sudden execution was announced by the president on the national TV. Consequently, raised prices were announced and enforced from the next day as they are illustrated in Table 2.1. In parallel with eliminating

[3]FOB stands for freight on board. FOB prices are usually used as a reference international price excluding transportation cost, taxes and any other overhead costs

a major part of price subsidies, lump-sum subsidies have been transferred to households. The amount of the lump-sum direct transfers in the first year after the reform was determined at 44.5 ITT per person and deposited to heads of households saving accounts[4].

2.3 Literature review

This section is structured in two distinctive parts. first, a review of studies of non-marginal tax/subsidy reforms, similar to what happened in Iran by the recent subsidy reform, is presented. Then, a berief review of the literature on modeling demand system is presented and then application of the model that is used in this study is justified for Iranian subsidy reform.

Price subsidy reforms, especially those aimed at energy and food, are meant to address inefficient targeting and the induced inequal distribution of the subsidies, to rule out distortions in the related markets, to fix governments' fiscal deficits, or to reduce environmental damages of fuel emissions. Regardless of the rational behind price subsidy reforms, they are commonly performed in an incremental, marginal manner. Non-marginal changes in prices, what is here termed as *Big Bang* approach, are usually avoided because of their unpredictable social consequences. Thus, there are just few infrequent cases of non-marginal price subsidy reforms and even fewer related researches. Apart from Iran's 2010 non-marginal energy and food price subsidy reform, which is the subject of this study, Nigerian case is an outstanding one. In January 2012, Nigiria abruptly eliminated fuel price subsidies and doubled fuel prices, as the highest single leap of prices in the country's history. Indonesia is also at the verge of launching a massive reform to eliminate fuel price subsidies that had emerged in the wake of 1998 Asian financial crisis.[5]

On the other hand, the rare studies of welfare effects of price subsidy reforms in developing countries do not use the most appropriate welfare measures partly because of data limitations. More specifically, the economic

[4]ITT, as it is defined here, stands for Iranian Thousand Tomans. One ITT can be translates to about $1 using the spot exchange rate in 2010 and 2011 (Iranian government was following a fixed exchange rate policy during the time of interest). Thus, through this study, ITT and $ values are used interchangably although Purchasing Power Parity (PPP) exchange rate in these years is $2.5 per 1 ITT.

[5]Indonesia was supposed to raise fuel prices in April 2012 but delayed the plan because of nationwide protests against the policy.

agents' monetary gains (or change in transfers between government and private sector) induced by an expected subsidy reform program have been the underlying criteria to judge about welfare consequences.[6]. This problem has been addressed in this study by computing exact welfare gains of households of different income groups in addition to computing households' mere monetary gains.

Legitimate studies of price subsidy reforms, however, consider marginal elimination of subsidies, as it is usually the case. From theoretical point of view, Ahmad and Stern (1984)'s paper founded the basis for marginal tax/price reforms. At the empirical side, Gahvari and Taheripour (2011), in midst of debates on reforming subsidy structure in Iran and right before execution of the subsidy reform, suggest an order for marginal and non-marginal cuts of different types of subsidies based on evaluation of the associated welfare gains. They employ the standard methodology that is most suitable for analyzing marginal changes in prices, but they use it for non-marginal changes as well. Taking similar analytical approaches for both cases is enforced by technical toolbox available to researchers since consumer theory is developed in a way to model consumers' responses to marginal changes given or exogenous factors such as prices. Likewise, welfare effects of non-marginal prices changes are analyzed using the theoretical framework that is essentially designed to analyze marginal price changes in this study.

Estimation of consumer demand system is central to the standard methodology for welfare evaluation. The most common model of consumers demand system is Almost Ideal Demand System (AIDS), introduced by Deaton and Muellbauers (1980). AIDS constitutes flexible demand functions that are consistent with consumer theory and also sui for welfare analysis.[7] AIDS,

[6]For instance, see Clarke and Menard (2002), Clements, Jung, and Gupta (2007), and del Granado, Coady, and Gillingham (2010).

[7]Household consumption data do not support linear demand functions derived from common specifications of utility function such as Cobb-Douglas and CES. They also have testing problem, i.e. they fail satisfying standard restrictions of consumer theory, especially homogeneity. The more advanced model of this type is the Rotterdam model proposed by Theil (1965) and Barten (1966). Using flexible functional forms in the empirical analyses of demand theory first introduced by Diewert (1971). The basis of Liewert's idea of modeling utility function was using functional forms with enough parameters so that it can reasonably approximate the true hidden utility function. Initial studies that exerted the idea of flexible forms used translogarithmic models as a second-order Taylor approximation of any implicit utility function (See Christensen, Jorgenson, and Lau (1975) for instance). Translog version of flexible forms, however, is not the most practical one because of enforcing unacceptable assumptions on demand functions such as quantities

however, embeds the rather strong assumption that the Engel curves of all goods are linear in terms of the logarithm of household's income or aggregate expenditure. This assumption is usually defied by empirical evidence. Engel curves often exhibit linear relationships instead.

Referring to the limitation on Engel curves, Banks, Blundell, and Lewbel (1997) introduced a generalized version of AIDS that allows nonlinearity in Engle curves, namely Quadratic Almost Ideal Demand System (QUAIDS), and applied it to the UK data. QUAIDS then are used in numerous studies like Blundell and Robin (1999) applied to the UK data but through a different econometric strategy, Moro and Schokai (2000) applied to Italian data, Abdulai (2002) applied to Switzerland data, and West and William (2004, 2007) applied to the US data, mentioned just as few of them. QUAIDS has also been applied on Iranian data first by Gahvari and Taheripour (2011). It is also chosen as the underlined model of this study with an re-organized categorization of goods and services and a different estimation method. Its application is verified by non-parametric depiction of shares of households' expenditures on the new categories of goods and services versus logarithm aggregate expenditure and observing that Engel curves for most of the categories are nonlinear.

2.4 The model

An economy is considered with households having the same preference structure and face similar prices in each quarter of year but their income levels are different. They have one unit of time endowment and supply all of it. They have access to n categories of goods and services to choose their consumption basket $\mathbf{x} = (x_1, x_2, ..., x_n)$. Markets of all of the categories of goods and services are competitive and they are produced by constant returns to scale technologies. This implies that optimal consumer and undistorted producer prices of all of the categories of goods and services are identical. Thus, the gap between the subsidized prices of food and energy and their corresponding first-best producer prices can be used to compute cash equivalent of price

determine prices instead of prices determine quantities and its complexity of implementation. Nonetheless, the flexible functional form that Deaton and Muellbauer exert and how their develop their model not only address the problems, but also does suit better for welfare analyses and optimal tax theory.

subsidies and welfare gain from the subsidy reform. Such computations will be performed having the estimation of the parameters of the indirect utility function of the representative household.

If households' preferences support the Quadratic Almost Ideal Demand System introduced by Banks, Blundell, and Lewbel (1997), then the indirect utility function of a representative household can be formulated as:

$$\ln \upsilon = \left\{ \left[\frac{\ln m - \ln a(\mathbf{p})}{b(\mathbf{p})} \right]^{-1} + \lambda(\mathbf{p}) \right\}^{-1} \tag{2.1}$$

in which

$$\ln a(\mathbf{p}) \equiv \alpha_0 + \sum_{i=1}^{n} \alpha_i \ln p_i + \frac{1}{2} \sum_{i=1}^{n} \sum_{j=1}^{n} \gamma_{ij} \ln p_i \ln p_j \tag{2.2}$$

$$b(\mathbf{p}) \equiv \prod_{i=1}^{n} p_i^{\beta_i} \tag{2.3}$$

$$\lambda(\mathbf{p}) \equiv \sum_{i=1}^{n} \lambda_i \ln p_i \tag{2.4}$$

where m is household's aggregate expenditure spent on the basket of categories of goods and services $\mathbf{x}$, $\mathbf{p}$ is the vector of price indices such that $\mathbf{p} = (p_1, p_2, ..., p_n)$, and α_0, α_i, β_i, γ_{ij}, and λ_i are parameters with $i, j = 1, 2, ..., n$. The parameters need to be restricted to satisfy the essential properties of a demand system, namely homogeneity of degree zero in income and prices, symmetry of Slutsky matrix, and adding up of the budget constraint. Formally, these properties can be translated to the following restrictions on the parameters of Equations 2.2-2.4:

$$\sum_{j=1}^{n} \gamma_{ij} = 0 \tag{2.5}$$

$$\gamma_{ij} = \gamma_{ji} \quad \text{for all} \quad i \neq j = 1, 2, ..., n \tag{2.6}$$

$$\sum_{i=1}^{n} \alpha_i = 0, \qquad \sum_{i=1}^{n} \gamma_{ij} = 0, \qquad \sum_{i=1}^{n} \beta_i = 0 \tag{2.7}$$

The first restriction, presented by Equation 2.5, guarantees homogeneity of degree zero. The second restriction, presented by Equation 2.6, ensures Slutsky symmetry. The third set of restrictions, presented by Equations 2.7, secure adding up property. It should be noted that the indirect utility function expressed by Equation 2.1 will reduce to Almost Ideal Demand System (AIDS), which enforces linearity of Engel curves, if $\lambda_i = 0$ for $i = 1, 2, ..., n$.

Given the indirect utility function expressed by Equation 2.1, demand functions for each of the categories of goods and services can now be derived by using Roy's identity. While the derived demand functions are the immediate candidates for estimation, it is simpler to estimate the categories' expenditure shares. In the following, it is shown how expenditure shares are related to demand functions, which themselves are derived by using Roy's identity:

$$\omega_i \equiv \frac{p_i x_i}{m} = \frac{p_i}{m}\left(\frac{-\partial \upsilon/\partial p_i}{\partial \upsilon/\partial m}\right) = -\frac{p_i}{m}\frac{-\partial \ln \upsilon/\partial p_i}{\partial \ln \upsilon/\partial m}$$

where ω_i indicates the expenditure share for category i of goods and services, $i = 1, 2, ..., n$. To find a simplified expression for expenditure shares, partial differentiation of the indirect utility function with respect to price and income need to be derived and inserted in above expression. Simplifications through incorporating Equations 2.2-2.4 and imposing symmetry restriction yield the following expenditure shares' system of equations:

$$\omega_i = \alpha_i + \sum_{j=1}^{n} \gamma_{ij} \ln p_j + \beta_i \ln \frac{m}{a(\mathbf{p})} + \frac{\lambda_i}{b(\mathbf{p})}\left[\ln \frac{m}{a(\mathbf{p})}\right]^2, \; i = 1, 2, ..., n \quad (2.8)$$

where logarithm of aggregate expenditure, m, is appeared in both linear and quadratic forms.[8]

Using Equation 2.8, income and price elasticities can be derived. In the followings, income elasticity of demand for good i, denoted by η_i, and uncompensated cross-price elasticity of demand for good i with respect to good j, denoted by ε_{ij}, are presented:

[8] In order to address heterogeneity of population in the sample, some researchers control for a vector of demographic factors, say z, by imposing more structure into the model. This, in practice, ends up to a modification of Equation 2.8 such that α_i and β_i will be replaced by terms like $\alpha_i + \theta_i z$ and $\beta_i + \varphi_i z$, respectively, where θ and φ are the parameters correspondent to z. This approach, however, is not applied to this study. Demographic factors are directly entered into regressions instead.

$$\eta_i \equiv \frac{\partial x_i}{\partial m} = \frac{1}{\omega_i}\frac{\partial \omega_i}{\partial \ln m} + 1 = \frac{1}{\omega_i}\left[\beta_i + \frac{2\lambda_i}{b(\mathbf{p})} + \ln\frac{m}{a(\mathbf{p})}\right] + 1 \tag{2.9}$$

$$\begin{aligned}
\varepsilon_{ij} \equiv \frac{\partial x_i}{\partial p_j}\frac{p_j}{x_i} &= \frac{1}{\omega_i}\frac{\partial \omega_i}{\partial \ln p_j} - \delta_{ij}, \\
&= \frac{1}{\omega_i}\Bigg\{\gamma_{ij} - \left[\beta_i + \frac{2\lambda_i}{b(\mathbf{p})}\ln\frac{m}{a(\mathbf{p})}\right] \times \\
&\quad \left(\alpha_j + \sum_{k=1}^{n}\gamma_{jk}\ln p_k\right) - \frac{\lambda_i\beta_j}{b(\mathbf{p})}\left[\ln\frac{m}{a(\mathbf{p})}\right]^2\Bigg\} - \delta_{ij}
\end{aligned} \tag{2.10}$$

where δ_{ij} is Kronecker delta. It is notable that both income and price elasticities will depend on income level if $\lambda \neq 0$. λ , in turn, gets nonzero value because of having the quadratic income term in the equation of expenditure share, i.e. Equation 2.8, that allows non-linearity in the Engel curve.

2.5 Data

In this section, it is explained what the main data sources are and how they are adjusted and employed to construct a workfile to be used in estimations. The main data sources are household's income and expenditure surveys (HIES) provided by the Statistical Center of Iran (SCI) and detailed urban price indices provided by the Central Bank of Iran (CBI). In addition to these main sources, to evaluate the real prices of the under-priced energy carriers and then compute the indirect monetary transfers or cash equivalent of price subsidies to households, energy production and consumption information are extracted from Energy Balance Sheets published by Iran's Ministry of Energy, international prices of energy carriers are obtained from OPEC's publications, and their export prices are found among the announcements and news of the websites of National Iranian Oil Company (NIOC) and National Iranian Gas Company (NIGC).

HIES are repeated cross-sections of household budget surveys collected, documented, and published by SCI from 1984. HIES contain information in four main parts: socio-economic characteristics, ownership, expenditures, and income. In Table 2.2 and Table 2.3, more details of the components of

HIES are shown. The last accessible HIES data set belongs in 2010. The surveys, which include information about both urban and rural households, are provincially and nationally representative in each quarter. The available HIES, hence, spans over 27*4=108 quarters.[9]

To have the biggest possible picture of households consumption behavior, it is desired to use all of the available data. However, for the initial years of the time period for which HIES are available, namely 1984 to 1986, number of observations is much less than that in the later years. In addition, the surveyed items of expenditures are very limited in compare to the other years. Hence, to have time-consistent repeated data sets, the first three years are dropped. Consequently, the number of time quarters shrinks to 95.

Part 3 of HIES contains information on households' expenditures in 14 categories. Each category contains several items and many sub-items, each specified by a commodity code. Through the time that HIES have been collected, the commodity codes, which are the main data processing tools, have been subjected to frequent changes. While there have always been year-to-year minor changes in the codes and increases or decreases in the number of items, substantial structural changes in commodity codes have also occurred in 1990 and 2004. In the absence of formal document to match commodity codes, in order to make the data contents of all years of HIES compatible, year-to-year changes in the codes assigned to every commodity are carefully tracked and transformed to those assigned from 2004. The time-consuming matching process of thousands of commodity codes has been performed for the first time in this study.

For the purposes of this study, the standard categories of goods and services, i.e. food, tobacco, clothing, housing, etc, as they are presented in Table 2.2, are not used. The subsidy reform is about eliminating price subsidies on energy carriers and necessary foods. But, there are no specific formal categories for energy and necessary food expenditures. Expenditures on necessary food items and different energy carriers are spread in several expenditure categories mixed with non-energy and non-food items instead. To be more specific, there are energy items among housing and utility expenditures, transportation expenditures, and durable expenditures. Also, there are both subsidized (necessary) and unsubsidized (unnecessary) food items

[9]HIES data are collected according to the Persian calendar. How Persian calendar is matched with Georgian calendar is explained later in this section.

among those listed under food expenditures.

In addition, knowing that public sector has the upper hand in the supply of education and health services at very low prices and the prices have not changed by subsidy reform, these items are dropped from the analyses to present a clear-cut contrast between items that carry price subsidies and the items that are transacted at their market prices before the subsidy reform.[10]

Therefore, to have categories of goods and services better matched with the analysis of the subsidy reform, new categories of goods and services are constructed. The new categories are: (1) subsidized food, denoted by SF;[11] (2) unsubsidized food, denoted by UF;[12] (3) non-energy-consuming goods, denoted by NE;[13] (4) energy-consuming goods, denoted by EG;[14] (5) energy, denoted by E;[15] (6) services, denoted by S;[16] (7) housing, denoted by H.[17] Having all the detailed expenditure information with uniquely assigned commodity codes throughout the entire time period, total expenditures on each of the new categories of goods and services are computed for each household.

Official price indices for the new categories of goods and services, of course, do not exist. To construct price indices for the categories, detailed monthly country-level prices indices of the Central Bank of Iran are used. In the first step, price indices of the items that their corresponding expenditures are used in the categories of goods and services are singled out. Then, their quarterly averages are computed to be matched with quarterly expenditure information in HIES. Finally, using the expenditure shares of the base year

[10]Education and health services are also partly delivered by private suppliers. HIES data, however, do not distinguish the expenditures on privately supplied education and health expenditures from the publicly supplied ones.

[11]The category of subsidized foods contains all of the food items that received price subsidy before the reform such as all types of bread, sugar, sugar cube, egg, and solid oil.

[12]The category of unsubsidized foods contains all other food, drink, and tobacco that did not receive price subsidy before the reform.

[13]The category of non-energy-consuming goods contains all the goods that do not consume any type of energy when used. This generally includes cloth, furniture, and the likes.

[14]The category of energy-consuming goods contains all the goods that consume some sort of energy when used. This generally includes electrical home appliances, heating and cooling apparatus, car, bike and the likes.

[15]The category of energy contains all sorts of energy that household consumes such as electricity for both home and transportation use, all types of fuels and energy carries used for house heating and cooling, transportation, any other non-business purposes.

[16]The category of services contains all types of services, except for education and health services, that household has spent for.

[17]The category of housing only contains two items: household's direct rent payments and rental equivalence of residing in the self-owned home.

2004 as weights, quarterly price indices of the new categories of goods and services are built up.

While very similar, the set of items for which the CBI publishes price indices is actually not exactly the same as the set of items for which HIES reports household expenditures. Therefore, only the expenditure items for which there exists CBI price index are used in the categories of goods and services and the rest are dropped.

The refined and adjusted new expenditure data are merged to the other household information, i.e. socio-economic characteristics, ownership, and income and the constructed price indices. This yields a complied body of different types of households information for each year. In the next step, workfiles of different years are appended to build a mega workfile for estimation. Since the CBI price indices are only for urban areas, rural households information is dropped from the workfile. In Table 2.4, number of urban households in the workfile in each year is listed. There actually are about 278 thousands of households in the workfile. Also, all the dates that are in Persian calendar are adjusted for western Georgian calendar as well.[18]

Since welfare analyses are performed for groups of households divided by deciles of "total expenditures"as proxy of income, in Table 2.5, the ranges of total expenditure, number of households and average household sizes across deciles in HIES 2010 are shown. The last two rows contain the same for the top five and top one percentiles, respectively.[19] Then, in Table 2.6, for

[18]In Persian calendar, a year precisely includes four natural seasons. A Persian year, hence, approximately coincides with last three seasons of a western year and the first season of the next western year. For example, the Persian year 1389, which is the last year for which HIES data are available, coincides with Spring, Summer, and Fall of 2010 and Winter of 2011. As a corollary, 2010 includes Winter of the Persian 1388 and Spring, Summer, and Fall of the Persian 1389. Backward running of this rearrangement procedure finally ends up to 1987, which should include Winter of the Persian 1366 and Spring, Summer, and Fall of the Persian 1367. As it was explained previously, HIES data for 1363 to 1366 are not used because of the abundance of mismatched items. As a result, 1987 only includes Spring, Summer, and Fall of the Persian 1367. This is why the number of observations in 1987 is much less than that in 1988 (Table 2.4).

[19]Total expenditure is defined different from aggregate expenditure. Aggregate expenditure contains expenditures on the new categories of goods and services and it is what is denoted by m in the model and used in the estimations. Whereas, total expenditure contains expenditures on new categories of goods and services plus expenditures on other goods or services that are not included in the new categories because of their irrelevance to this study such as expenditures on health and education, unavailability of their corresponding CBI prices, or any other data matching reason. Total expenditure, instead of aggregate expenditures m, has been used to divide households into deciles because it present a closer approximation of households' income. Having this in mind, groups of

the same group of households, the shares of aggregate expenditure spent on each category of goods and services are presented. The figures show that the shares of aggregate expenditure spent on both subsidized and unsubsidized food and housing diminish when moving toward higher deciles. A reverse trend is seen for the shares of aggregate expenditure spent on both non-energy- and energy-consuming goods and services. Although the share of energy expenditures in aggregate expenditure is small,[20] it increases slightly from lower to median deciles, then decreases slightly toward higher deciles.

2.6 Engel curves

QUAIDS model allows quadratic Engel curves. To check tentatively how relevant application of QUAIDS model to Iranian household expenditure data is, the relationships between shares of aggregate expenditure and the logarithm of aggregate expenditures and the square of the logarithm of aggregate expenditure are estimated through simple linear regression models. The regressions are run for the whole time period using real income, for the last year data (2009), for a mid year (2000), and for an early year (1990) and their results are presented in Tables 2.7 and 2.8. Moreover, non-parametric kernel regressions and quadratic polynomial regressions for the categories of goods and services are graphed in Figures 2.12.4.

The regressions support quadratic relationship for all categories of goods and services when the data from entire time period is considered. The quadratic relationship is also supported in the selected years with a decade of distance except for housing in 1990 and 2000. These observations are also consistent with what the figures show.[21] thus, it seems using a preference structure that allows for nonlinear Engel curves is supported by the data.

households shaped by total expenditure are called income groups.

[20] The share is much smaller in total expenditure, as it is expected.

[21] The figure were also drawn for the specific years of 1990, 2000, and 2010. The shapes remain generally unchanged.

2.7 Estimation procedure and results

Empirical Engel curves, showed signs of quadratic relationship between the the shares of the categories of goods and services and real aggregate expenditure. This implies inclusion of the square of households' aggregate expenditure as an explanatory variable in the right hand side of Equation 2.8 that exemplifies a typical equation of households' demand system. In this section, details of estimation procedure of the demand system is explained in this section.

The demand system consists of 7 equations, each for one of the 7 categories of goods and services. Every demand equation, in turn, contains 10 parameters (γ_{i1},γ_{i2},...,γ_{i7},α_i,β_i,λ_i). Subsequently, there are 70 ($= 7 \times 10$) parameters to be estimated. The equation for category of "housing"is dropped from direct estimation procedure to get its parameters recovered from adding up restriction. This leaves 60 parameters to be estimated. In addition, the price index of the same category, housing, is taken as numeraire, and then the price indices of other categories of goods and services and aggregate expenditure are measured relative to housing price index. This, finally, reduces the number of parameters by 6 and leaves 54 parameters to be estimated.

The chosen strategy to estimate the system of demand equations is a two-stage procedure a la Banks, Blundell, and Lewbel (1997) in which $a(\mathbf{p})$ and $b(\mathbf{p})$ are computed using an iterative routine of estimating parameters in the first stage and obtaining the final estimation of parameters in the second stage by imposing all the restrictions, given the values of computed $a(\mathbf{p})$ and $b(\mathbf{p})$. However, how the second stage is performed here, different than Banks, Blundell, and Lewbel (1997)'s method, is adopted from West and Willims (2007). In what follows, how each stage is performed is described in details.

The first stage of the estimation procedure comprise an iterative procedure to compute $a(\mathbf{p})$ and $b(\mathbf{p})$. First, initial values are assigned to the parameters in $a(\mathbf{p})$ and $b(\mathbf{p})$ i.e. α_0, α_1, α_2,..., α_6, β_1, β_2, ... , β_6, and γ_{ij}'s. The initial values assigned to all of the parameters, except for α_0, are chosen randomly from a uniform distribution of numbers between zero and 0.01. The assigned values, except for α_0, will then get updated through the iteration procedure that will be described after justifying the initial value assigned to α_0.

Deaton and Muellbauer (1980) show that α_0 can be interpreted as the level of expenditures that would be needed for subsistence or minimal standard of living if all prices are set to be equal to one. To apply this idea and find the relevant value for α_0 in the prepared workfile of Iranian household surveys, poverty line in 2004, i.e. the base year of the price indices, is computed and employed. To do so, Assadzadeh and Paul (2004)'s computation of poverty line in Iran's urban regions in 1989 is updated for inflation to get its 2004 value and assign to α_0. In the poverty line computation, both dietary and non-dietary components of households' expenditures are considered.

Plugging the initial value of α_0 and random initial values of other parameters in the formula for $a(\mathbf{p})$ and $b(\mathbf{p})$ given by Equations 2.2-2.4 gives the initial values for $a(\mathbf{p})$ and $b(\mathbf{p})$. These, in turn, are used in estimation of the demand system represented by Equation 2.8. In practice, each of the 6 demand regressions (the regression for housing is dropped to be recovered later by adding up restriction) is estimated separately with the OLS model in which household size, the gender of households' heads and province of residence are inserted as covariates. The estimated parameters of the 6 demand regressions and the computed parameters for the 7th from the adding up restriction, then, are used to update the initially computed values of $a(\mathbf{p})$ and $b(\mathbf{p})$. This procedure is repeated as many times as required to achieve convergence for $a(\mathbf{p})$ and $b(\mathbf{p})$ in the tolerance level of 0.00001.

As it was mentioned, adding up restrictions are satisfied in the first stage by dropping the category of housing and then recovering its parameters by applying the restrictions. Homogeneity restrictions are also satisfied in the first stage by using relative-to-housing-price-index values. This ensures that proportional changes in price indices and aggregate expenditure will not change expenditure shares. Symmetry restrictions, however, are not satisfied in the estimation procedure of the first stage. To address symmetry restrictions is a reason to undertake another series of estimation.

In addition to the concern about satisfying the symmetry restrictions, the first stage estimations potentially suffer from endogeneity and cross equation correlation of errors. Endogeneity can emerge from using households' aggregate expenditure as their income in the right hand side of the regressions while having shares of categories of goods and services in aggregate expenditure as dependent variables. In addition, since all the right hand side explanatory variables of the first stage OLS regressions are identical, their error terms are possibly correlated.

To address the the listed concerns, i.e. to impose cross equation symmetry restrictions, control for endogeneity of aggregate expenditure, and account for correlation of error terms across equations, similar to West and Williams (2007), a three-stage least squares regression routine (3SLS) is adopted. 3SLS, apart from allowing to force cross-equation parameter restrictions, puts two-stage least square regression routine (2SLS) together with seemingly unrelated regression model (SUR) to control for both endogeneity of aggregate expenditure with instrumental variables and endogeneity of error terms with taking into account the correlated error structure, respectively.

In practice, aggregate expenditure are instrumented with demographic variables (head's age, dummy variable for head's literacy, head's years of education, and head's employment status), ownership variables (type of ownership of residence, area of the place of residence, dummy variables separately for ownership of TV, refrigerator, freezer, vacuum cleaner, and washer), job-related variables (number of self-employed jobs hold by head, number of wage-and-salary jobs hold by head, head's job title, head's main activity at workplace, and dummy variable for the main job in public/private sector), and logarithm of real price of oil.

The 3SLS estimation of the coefficients of the demand system are reported in Table 2.9.[22] Observing that the estimated coefficients for aggregate expenditure squared are statistically insignificant for the cases of energy-consuming goods and energy, aggregate expenditure squared is not included among the explanatory variables of the corresponding equations. The demand system, thus, is re-estimated after applying this adjustment[23]. The results presented in Table 2.9 are for the adjusted version.

The estimation results show that the coefficients of aggregate expenditure squared are strongly significant in the equations for subsidized food, unsubsidized food, non-energy-consuming goods, and services justifying imposition of non-linear Engel curve structure. Own-price coefficients, while statistically insignificant, are negative for energy-consuming goods and services, which implies that absolute values of own-price elasticities for energy-consuming goods and services are likely to be more than one that means they have elastic demands as one expects. In the contrary, own-price coefficients are statistically significant and positive for subsidized and unsubsidized food,

[22]To fit the results just in one table, coefficients of the dummy variables for households' province of residence are not reported.

[23]The results of the re-estimation are almost exactly the same as the the former results.

non-energy-consuming goods, energy and housing indicating that absolute values of own-price elasticities for these categories are more likely to be less than one that means they have inelastic demands as one may expect.[24]

The estimated coefficients reported in Table 2.9 are then plugged into Equations 2.9 and 2.10 to calculate elasticities. The calculated uncompensated own-price, aggregate expenditure, and compensated own-price elasticities for a household with average size, average income, and male head are reported in Table 2.10. Going over uncompensated own-price elasticities, all categories of goods and services have inelastic demands except for energy-consuming goods and services. The most inelastic category is subsidized food as it is actually expected. Income elasticities of subsidized and unsubsidized food are less than one verfying that they are necessary goods. For non-energy-consuming-goods, energy, and housing, income elasticities are about unity, while energy-consuming goods and services can be considered luxurious with income elasticities that are larger than one. All of the income elasticities are positive meaning that all of the categories represent normal goods. This also implies that uncompensated price elasticities are larger than the corresponding compensated price elasticities in absolute value.

In terms of compensated price elasticities, similar to uncompensated price elasticities, all categories of goods and services have inelastic demands except for energy-consuming goods and services. Energy-consuming goods have elastic compensated price elasticities while it is about unity for services.

Table 2.11 reports the values of uncompensated cross-price elasticities for the seven good categories (again for a household with average income). The interesting observation here is that energy and subsidized food, the two highly subsidized categories, are complements (their cross-price elasticities being negative). Aggregate welfare loss increases when the two subsidized goods are complementarity. This follows because subsidizing one category implicitly subsidizes the other and leads to more revenue loss to the government and thus a higher welfare loss (than if the two were substitutes). On the other hand, the fact that energy and subsidized food have inelastic demands, helps reduce the welfare loss associated with their subsidization. One counterintuitive finding reported in Table 2.11 is the positive value for the cross-price elasticity between energy and energy consumer goods. One would

[24]Since the coefficients of the equation for housing are recovered by adding up conditions, standard errors cannot be computed for them neither statistical inference.

expect these goods to be complements and not substitutes (as indicated by a positive cross-price elasticity).

2.8 Expected change in monetary transfers to households implied by the reform

Change in the cash equivalent amount of energy and food price subsidies added by post-reform rebates puts forward an initial assessment of change in households' benefits from the subsidy reform and a rough idea about winners and losers of the reform. Such an assessment is mainly intended to gauge the size of monetary transfers between households and government right before and after the reform, but it does not take into account the substitution effects passing through households' utility function. Thus, the amounts of monetary transfers must not be interpreted as exact welfare effects of the subsidy reform. They, however, are more relevant in investigating the effect of the reform on fiscal situation of government. Keeping the remarks in mind, in this section, cash equivalent amount of pre-reform food and energy price subsidies are computed first. It is also shown that the subsidy reform does not eliminate food and energy subsidies completely, thus a similar calculation is repeated in post-reform conditions. Pre-reform and post-reform cash equivalent transfers are finally compared, direct rebates are included, and the net change in total cash transfers is computed.

To transform pre-reform price subsidies for food and energy to their equivalent monetary values, expenditures on subsidized food items and energy carriers are extracted from 2010 sample of households. Applying food items' and energy carriers' subsidy rates on the corresponding expenditures, then, gives the cash equivalent of the price subsidies paid to a household with given levels of consumption of those goods. Subsidy rates are separately computed as deviation of pre-reform prevailed prices of the goods from their opportunity costs. Formally speaking, if xsf_j^h and xe_k^h denote consumption of household $h = 1, 2, ..., H$ from subsidized food item $j = 1, 2, ..., J$ and energy carrier $k = 1, 2, ..., K$, respectively, $\mathbf{ssf} = (ssf_1, ssf_2, ..., ssf_J)$ and $\mathbf{se} = (se_1, se_2, ..., se_K)$ denote the vectors of food and energy subsidy rates, respectively, and $\mathbf{psf} = (psf_1, psf_2, ..., psf_J)$ and $\mathbf{pe} = (pe_1, pe_2, ..., pe_K)$ denote the vectors of subsidy-free food and energy prices (or opportunity costs of food and energy), respectively, then the cash equivalent of food and energy price subsidies that household h receives can be expresses as:

$$S(sf)^h = \sum_{j=1}^{J} ssf_j \; . \; xsf_j^h(\mathbf{psf} - \mathbf{ssf}, m^h) \tag{2.11}$$

$$S(e)^h = \sum_{k=1}^{K} se_k \; . \; xe_k^h(\mathbf{pe} - \mathbf{se}, m^h) \tag{2.12}$$

where m^h is household h's income.

It is assumed that post-reform food prices reflect the opportunity cost of pre-reform subsidized food. Then, pre-reform subsidy rates for the subsidized items of food are computed as the deviation of their pre-reform prices from their post-reform prices. For energy carriers, however, post-reform prices cannot simply be taken as opportunity costs because of the existence of international markets for energy carriers in which prices fluctuate in day basis and the fact that post-reform prices are not necessarily the same as international prices.

Energy carriers that households reported consuming are (1) gasoline for transportation use, (2) gas oil for transportation use, (3) gas oil for residential heating, (4) compressed natural gas (CNG) as fuel for automobile, (5) liquefied natural gas (LNG) for residential cooking, (6) piped natural gas for residential cooking, heating , and lightening (7) fuel oil for residential heating, (8) kerosene, and (9) electricity. For direct products of oil, i.e. gasoline, gas oil, fuel oil, and kerosene, their international market prices provide the bases to compute their opportunity costs. The same is true for CNG and LNG.[25] Prices of electricity and natural gas, however, differ considerably around the world with no integrated international market, making it difficult to pin down some international prices as the bases for opportunity cost computations. In these cases, the average per unit prices of export to the neighboring countries are used as the bases for opportunity cost computations[26]

[25] In practice, Persian Gulf FOB prices are taken from OPEC reports as the international prices for Iranian oil products, CNG, and LNG. A 10% distribution costs is added to these to obtain the opportunity costs. The dollar value opportunity costs, then, are transformed to ITT using the prevailed fixed exchange rate of 1 ITT per a US dollar.

[26] The required information is extracted from the website of National Iranian Gas Company (NIGC) and Energy Balance Report published by Iran's Ministry of Energy. A 30% distribution costs is added to them to obtain the opportunity costs. Again, The dollar value opportunity costs are then transformed to ITT using the prevailed fixed exchange

Since households of different income groups vary in their consumption of the food items and energy carriers, they differ in the cash equivalent amount of price subsidies that they receive. To open up on this, the cash equivalent of transfers (or monetary value of price subsidies) are computed for average income household of each decile, of top 5%, of top 1%, and of the whole sample of 2010.

The results of computing the cash equivalent of pre-reform price subsidies are presented in Tables 2.12 and 2.13. In Table 2.13, break down of cash equivalent of pre-reform price subsidies on energy carriers is presented. The following takes of the results are noteworthy: (1) households get the biggest amounts of energy price subsidies on natural gas, gasoline, electricity, and kerosene, respectively. This is no surprise because they are the main sources of energy for urban households; (2) the amounts of energy price subsidies were remarkable in any standard. For example, an average household received energy price subsidies equivalent to about $262 in the monthly basis. Moreover, energy subsidies come to more than 80% of the total expenditure of an average household from the lowest decile of total expenditure. By no means, energy price subsidies are negligible even for the richest households whose benefit from them comes to about 30% of their total expenditure; (3) except for gas oil, fuel oil, and kerosene, the richer consistently benefited more than the others from all types of price subsidies on energy.[27] In fact, what the households from higher deciles of total expenditure used to receive in the form of energy price subsidies was tremendously more than what those from lower deciles did. For instance, what an average household from the highest decile received via all energy price subsidies was about 7 times more than what an average household from the lowest decile received; $616.871 versus $90.417; (4) the inequality in receiving energy price subsidies are gigantic in the case of gasoline. As a matter of fact, an average household in highest decile received gasoline price subsidy as about 30 times as what an average household in lowest decile did. This figure is about 6 and 5 for natural gas and electricity, respectively.

In Table 2.13, break down of cash equivalent of pre-reform price subsidies

rate of 1 ITT per a US dollar.

[27] Gas oil and fuel oil are the least popular sources of energy, thus there are few related observations in the data set. Hence, the no-pattern situation is mainly rooted in the lack of sufficient data.

on subsidized food items is presented. In comparison to energy subsidies, food subsidies are much lower such that an average household received about \$19 in cash equivalent of food subsidies. Again, it can be seen that the richer households consistently receive more of food subsidies on all of the subsidized items. The inequality in distribution of food subsidies, however, is less severe than that of energy subsidies. Similar to the case energy price subsidies, if subsidy distribution inequality is measured by the ratio of the cash equivalent of price subsidies received by the highest decile to that received by the lowest decile, the figure for all food subsidies is about 3 and between 2 and 6 for different food items. As a hint from the given account of pre-reform price subsidies, an average household received an equivalent amount of \$281 per month as energy and food price subsidies, above 92% of it was energy subsidies.

Evaluating post-reform energy price subsidies is motivated by the fact that post-reform price of energy carriers were still deviated from their opportunity costs. Thus, applying post-reform subsidy rates on post-reform consumption of energy carriers will yield the cash equivalent of post-reform energy subsidies. Post-reform consumption of energy carriers, however, is not available since post-reform household budget survey, i.e. HIES 2011, is not yet available. Nevertheless, estimation of households' demand system allows predicting households' consumption of energy carriers in a year after the subsidy reform invoking new price levels. Using the prediction of aggregate energy consumption and assuming that the shares of consumption of different energy carriers in aggregate energy consumption remains the same as their pre-reform levels, households' consumption of different energy carriers can then be computed. Finally, applying post-reform subsidy rates to the predicted consumption of energy carriers gives the cash equivalent of post-reform energy price subsidies. Formally, if $\mathbf{se}' = (se'_1, se'_2, ..., se'_K)$ denote the vectors of post-reform energy subsidy rates, then the post-reform cash equivalent of energy price subsidies that household h receives can be expresses as:

$$S(e)'^h = \sum_{k=1}^{K} se'_k \, . \, xe^h_k(\mathbf{pe} - \mathbf{se}', m^h + n^h a) \qquad (2.13)$$

where n^h is the number of the members of household h and a is the amount of direct rebate.

Break down of post-reform cash equivalent of energy price subsidies reported in Table 2.14 shows that energy price subsidies, in general, were reduced considerably by the subsidy reform from about $262 to about $78 per month for an average household. Decrease in price subsidies on natural gas and gasoline are majorly responsible for the reduction such that the cash equivalent of natural gas and gasoline price subsidies diminished from about $145 and $66 to about $37 and $3 per month, respectively. In spite of the considerable decrease in natural gas price subsidy, it still constitute almost the half of the post-reform price subsidies with about $37 per month for an average household. Inequality in the distribution of non-eliminated energy subsidies is still remarkable as it used to be.

To evaluate the change in the monetary transfers induced by the subsidy reform, post-reform direct rebates to households need to be added to post-reform cash equivalent of energy price subsidies and then the summation should be compared to pre-reform cash equivalent of energy and food price subsidies. This is done in Table 2.15. Column S, which contains cash equivalent of all pre-reform price subsidies, is actually the summation of columns Sum from Tables 2.12 and 2.13. Column S', which contains cash equivalent of post-reform energy price subsidies, is transferred from column Sum in Table 2.14. And, Column A, which contains direct rebates to households, is computed by multiplying the average household size in each income group by the amount of the post-reform uniform rebate, which is 44.5 ITT per person per month. The change in monetary transfer, then, can be computed by $\Delta R = A + S' - S$. The results are recorded in the last column of Table 2.15 and show that subsidy reform led to an about $46 loss per month in cash equivalent for an average household. However, if only the monetary transfers are considered (as it is the case here), the lower half of the population in terms of total expenditure actually benefit from the subsidy reform in the expense of the higher half. It seems that the subsidy reform led to an enormous income redistribution in which half of the urban population are the losers, but the other half are the winners. More specifically, the lower total expenditure is, the more the benefits are; but the higher total expenditure is, the more the loses are. It should be reminded that the results of computing the net cash equivalent of transfers must not form the ultimate judgment about the welfare effects of the subsidy reform. A more relevant criterion has to passes the changes in the monetary transfers through consumers' utility functions and takes the reduced price distortions into account. This issue is addressed in Section 10.

2.9 Household- and society-level welfare gains

In Section 8, the change in the amount of subsidies paid to urban households was computed. Change in subsidies paid to households is actually equal to the change in government's transfers to households. If the effects of the subsidy reform were confined to a change in government's transfers to households and if transfers to households of different income groups had the same social value, then positive and negative transfers would have nullified each other and might made the net effect of the reform zero. The conditions for none of the "if"s, however, are fulfilled. First, altering the cash equivalent of transfers is not the only attainment of the reform; the prices have also changed and become less distortionary, closer to their real values. The delicate implication of this economic reality is that the reform, which replaced a big chunk of price subsidies with direct transfers, makes households better off even if the net government transfers to them is zero. In other words, receiving an amount in cash increases households' welfare more than paying the same amount in the form of price subsidy because households can spend the cash on whatever is more desirable form them, while they enjoy price subsidies only if they consume subsidized goods. Second, if society cares about equality, then it assigns more value to transfers to the poor than the transfers to the rich. In this section, the notion of equivalent variations, EV, is used to evaluate welfare gains of households of different income groups induced by the reform. The notion of social equivalent variations is then used to summarize all the welfare gains from society's point of view.

A household's welfare gain from the subsidy reform can be measured by equivalent variations, EV. EV^h measures household h valuation of subsidies and can be found in:

$$\upsilon^h(\mathbf{p}-\mathbf{s}, m^h + EV^h) = \upsilon^h(\mathbf{p}-\mathbf{s}', m^h + n^h a) \tag{2.14}$$

To be more specific, EV^h is the amount of money household h would be willing to give up to prevent the subsidy reform (or, it is the change in income that would get household h to the after reform utility level as the reform would if it happened). A positive EV^h, as it is defined in Equation 2.20, implies household's unwillingness to change while the negative EV^h implies household's willingness to change. Negative of EV^h, hence, can be interpreted as household h's welfare gain from the subsidy reform.

The results of EV calculations for different income groups are reported in Table 2.16. The results show that only the households in the top decile would not agree with the reform. More specifically, urban households in the first, second, third, ... , eight, and ninth deciles would gain about \$61, \$63, \$60, ... , \$–37, and \$–150 per month to prevent the subsidy reform (these values can also be interpreted as their welfare gains). This finding, that 70% of households better off with the reform, is close to the finding in Section 8, that 60% of households gain monetarily from the reform.

To evaluate the welfare gain of the society as a whole due to the subsidy reform, a social welfare function is required in the first place. Atkinson (1973) iso-elastic welfare function makes it feasible to apply a wide range of attitudes towards inequality in the society. It is defined as:

$$\begin{aligned} W &= \frac{1}{1-\rho}\sum_{h=1}^{H}\pi^h(\upsilon^h)^{1-\rho} \qquad \rho \neq 1 \quad 0 \leq \rho < \infty \\ &= \sum_{h=1}^{H}\pi^h \ln \upsilon^h \qquad\qquad\qquad \rho = 1 \end{aligned} \tag{2.15}$$

where $\rho \geq 0$ is the inequality aversion index, which determines society's attitude toward inequality such that $\rho = 0$ and $\rho \to \infty$ indicate utilitarian and Rawlsian welfare function, respectively. Equation 2.1 with parameters specified by Equations 2.2-2.4 that is estimated through the described QUAIDS procedure in Section 7, determines the functional form of υ^h.

Given the social welfare function specified by Equation 2.21, the notion of the "social equivalent variations", EV^s, is employed. EV^s is defined analogously to the notion of equivalent variations for a household, Equation 2.14. Thus, EV^s is specified as:

$$\sum_{h=1}^{H}\pi^h\left[\upsilon^h(\mathbf{p}-\mathbf{s}, m^h + EV^s)\right]^{1-\rho} = \sum_{h=1}^{H}\pi^h\left[\upsilon^h(\mathbf{p}-\mathbf{s}', m^h + n^h a)\right]^{1-\rho} \tag{2.16}$$

Based on the definition, EV^s is the amount of money every household in the society would be willing to give up to prevent the subsidy reform. A positive EV^s, similar to EV^h, implies society's unwillingness to accept the subsidy reform.

The results of computing EV^s for six different values of the inequality aversion index, ρ, are reported in Table 2.17. It is remarkable that under all different attitudes toward inequality in the society, social equivalent variations are positive indicating society's willingness to accept the subsidy reform. The values of EV^s, indicating society's welfare gain, span in a range of about \$14 to \$61 per urban household per month, which seems to be reasonable in compare to the range of EV^h's. As it is expected, EV^s is larger for bigger values of ρ, when society put more value on inequality.

2.10 Conclusion

In this paper, change in the monetary transfers to households, fiscal consequences, and welfare gains induced by the massive 2010 energy and food subsidy reform in Iran are evaluated. To achieve these goals, the results of estimating Iranian economy's Quadratic Almost Ideal Demand System are used. The demand system consists of seven unconventional categories of goods and services. In particular, the conventional categories of food, cloth, housing, furniture, transportation, health, education, miscellaneous, and durables are broken and recomposed to seven categories of unsubsidized and subsidized food, non-energy-consuming goods, energy-consuming goods, services, energy, and housing. To estimate the demand system, the longest consistent series of household budget surveys are employed, i.e. Household Income and Expenditure Surveys from 1987 to 2010, which is the year right before the reform's execution. Only the information of the residents of urban areas, who form about 71% of the population, are used in the estimation to be matched with the urban price indices.

First, cash equivalent of pre-reform and post-reform energy and price subsidies are estimated. The gigantic size of pre-reform price subsidies are portrayed so that energy subsidies amount to more than 80% of the total expenditure of the poorest households and even about 30% of the rich households. The inequal nature of the pre-reform price subsidies are also demonstrated.

In particular, cash equivalent of transfers in the form of energy price subsidies to an average household from the highest decile of total expenditure was about 7 times more than that to an average household from the lowest decile of total expenditure. The inequality was monstrous in the case of gasoline, ranked as the second source of household's energy. In effect, the corresponding transfers to an average household in the highest decile of total expenditure was about 30 times bigger than transfers to an average household in the lowest decile of total expenditure. Since all energy price subsidies were not eliminated by the reform, especially there are still sizable price subsidies on natutal gas and electricity, such estimations are repeated in the post-reform year. Finally, the net change in the monetary transfers to households of different total expenditure groups, including direct rebates, are computed. The results show that the subsidy reform increases the net transfers to low-income half of urban households while it decreases for high-income half, although an average urban household undergo a decline.

Second, the influence of the subsidy reform on government's fiscal condition analyzed. In particular, for an average household of any income groups, government's revenues and expenditures are computed. In average, government's net domestic revenue from reducing energy subsidies, i.e. increased revenue from selling any unit of energy carriers at higher post-reform prices minus decreased revenue from selling less of them in the post-reform year, is positive and about \$26 per urban household per month. The same figure from eliminating food price subsidies is also positive and about \$45 per urban household per month. Net of rebate total net domestic revenue, i.e. net domestic revenue from reducing both energy and food subsidies minus rebate, for an average household is considerably negative and about \$03 per urban household per month. Thus, if government's potential foreign revenue from selling the decreased domestic consumption in the international market, which is a sizable amount for energy carriers, are not incorporated, then government faces huge loss in its accounts. The foreign revenues incorporated, everything else kept equal, government is expected to make a profit of about \$46 per urban household per mouth.

Third, welfare gains of the households of different income groups and the society as a whole are computed. Computing households' equivalent variations demonstrate that only the top 30% households will be left unfortunate with the subsidy reform. The rest of the urban households benefit from the subsequent welfare gains. This result is not in conflict with the results of computing the change in transfers to households, that showed the top % of the urban households take monetary advantage from the reform. Since equivalent variations provide credible evaluation of welfare changes by absorbing the gains from less distorted prices, the corresponding results reflect the more reliable welfare effects. Computing social equivalent variations show increased welfare gains by the reform as well.

It should be noted that the evaluations of monetary transfers, governments fiscal condition, and welfare gains are subjected to continuous changes caused by ongoing changes in the prices of energy carriers in the international markets. On this account, energy prices are required to be constantly updated according to their opportunity costs in the international markets, so is the amount of the rebate. Therefore, introducing the next phases of the reform is inevitable.

Finally some caveats should be taken into consideration when interpreting the results of this study. The impact of elimination of energy subsidies on producers, who did not receive any rebate, is ignored in this study. Imposing this simplifying assumption that potentially biases welfare estimates is unavoidable because of the scope of this study. Bearing this in mind, the reported welfare estimates provide the upper bounds of the welfare effects of the subsidy reform. On the other hand, this study does not considers the welfare enhancing impacts of the reduced emission caused by declined consumption of energy.

Figure 2.1: Estimated Engel curve for subsidized and unsubsidized foods at average income

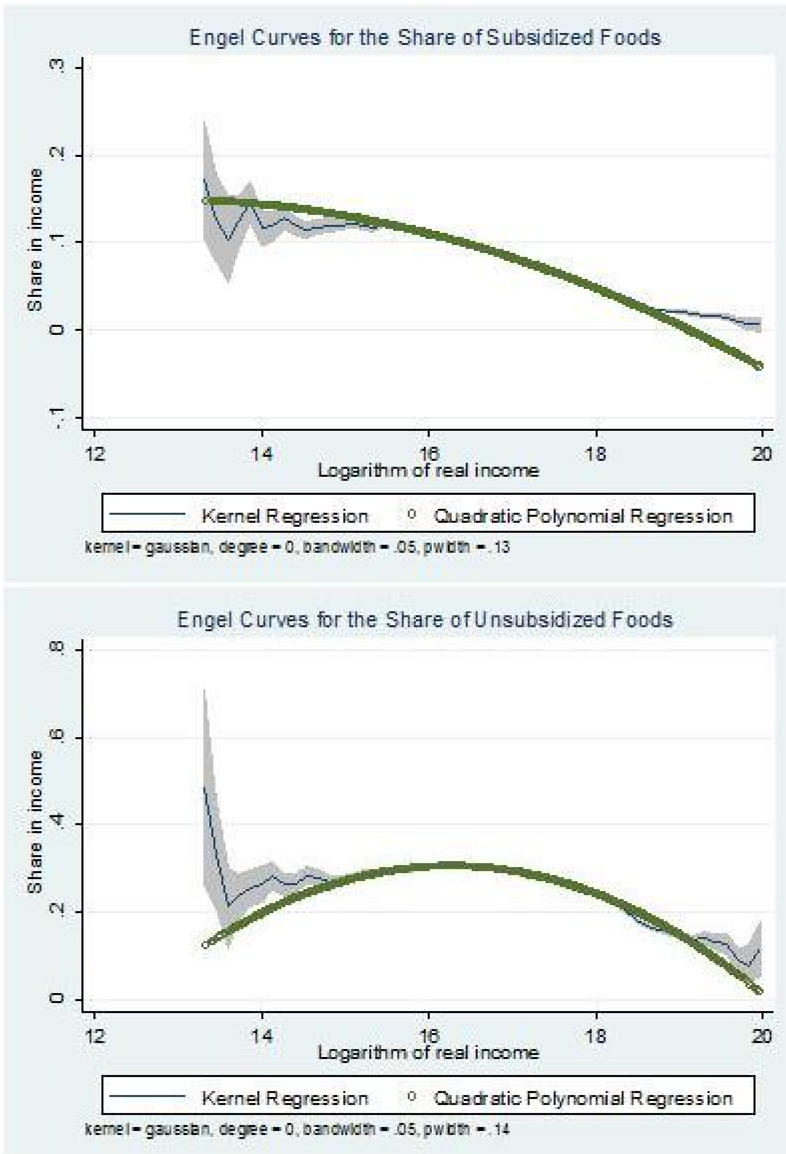


Figure 2.2: Estimated Engel curve for non-energy- and energy-consuming goods at average income

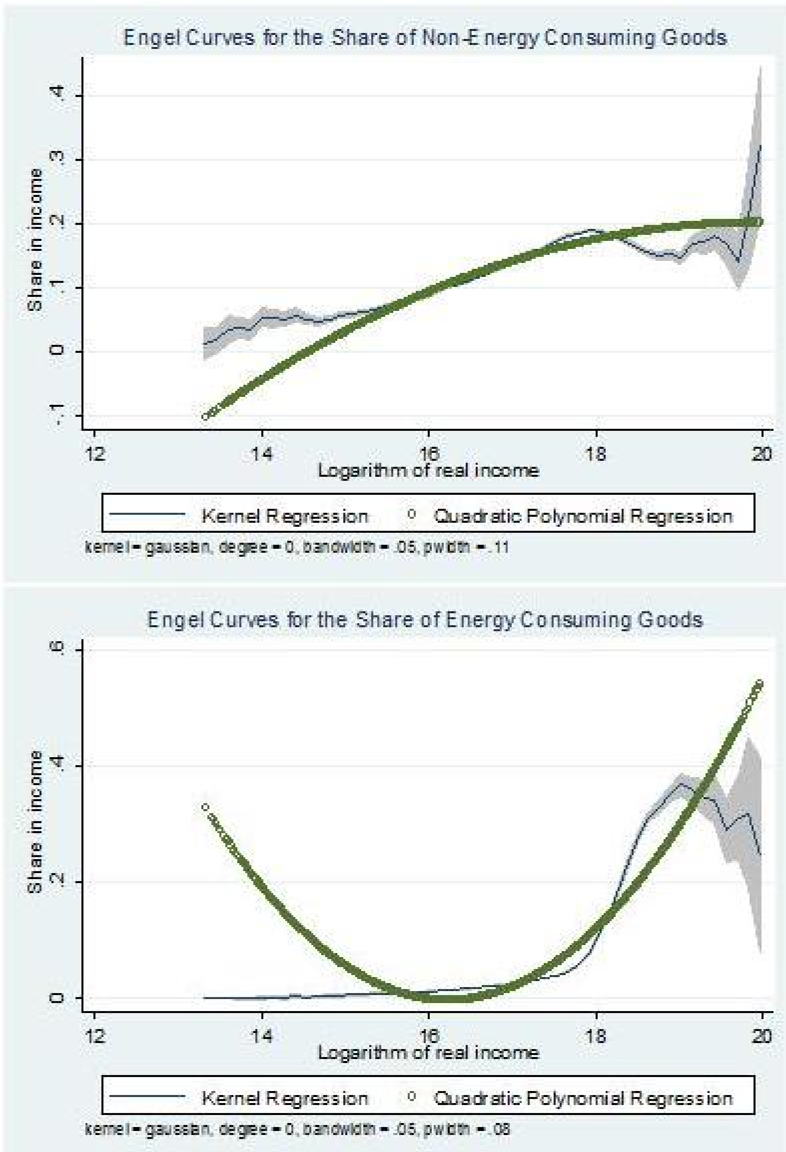


Figure 2.3: Estimated Engel curve for services and housing at average income

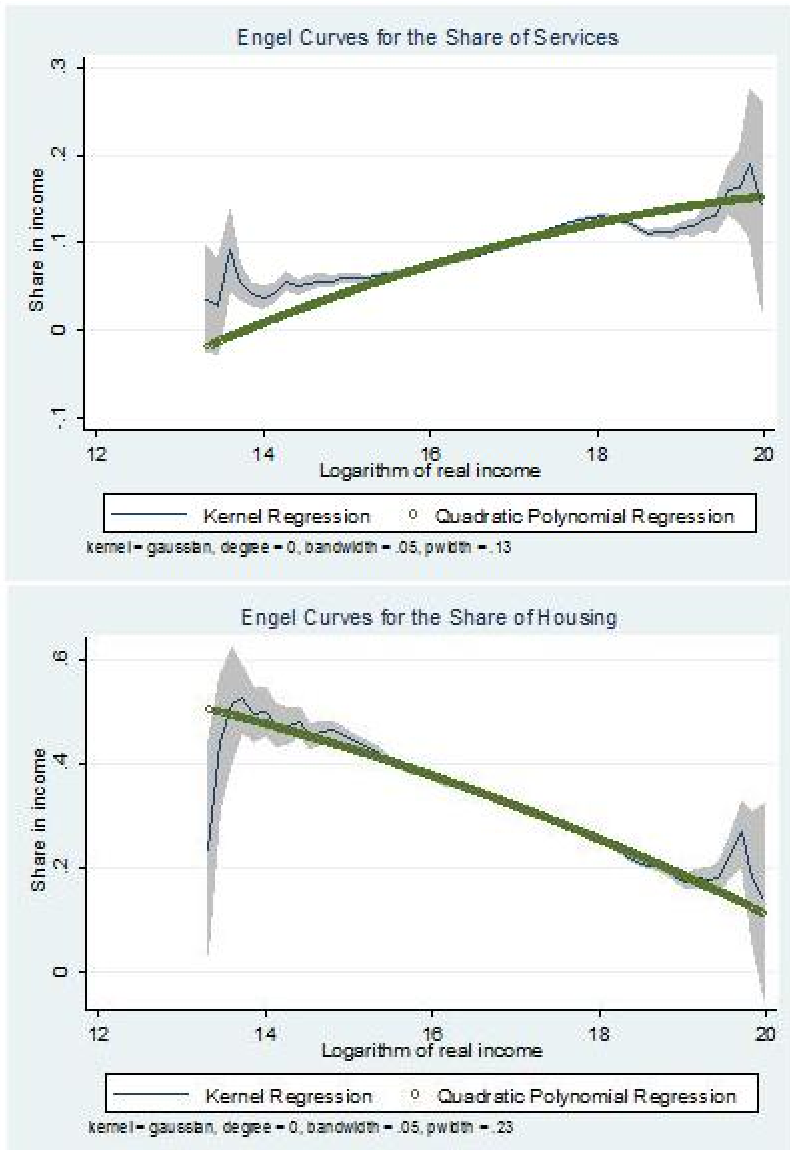
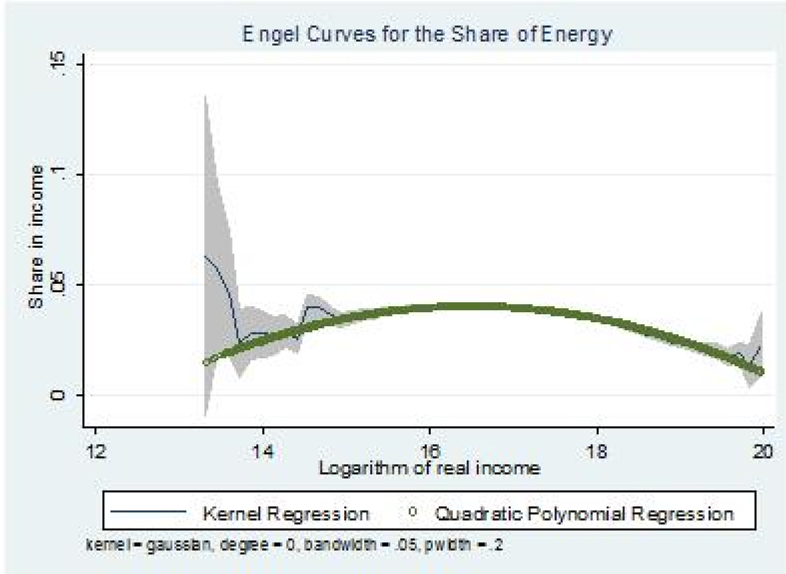


Figure 2.4: Estimated Engel curve for energy at average income



Notes: (1) The pre-reform and post-reform prices of the items of "Energy" section are in Rials. These are taken from Announcement 1 to 5 of the Bureau of Targeting Subsidies (BTS) published in www.dolat.ir. (2) The pre-reform and post reform prices of the items of "Subsidized Foods"section are the related price indices where 2004 is the base year. Since BTS did not mention the exact pre-reform and post-reform prices of the items in its announcements, we initially collected them by our own field experiment. Then, for the sake of consistency and comprehensiveness, we used the Central Bank of Iran's price indices.

Table 2.1: Pre-reform and post-reform prices and the percentage increases

	unit of measure	Pre-Reform Prices	Post-Reform Prices	Percentage Increase
Energy:				
Gasoline	liter	1000	7000	600
Gas Oil - Transportation Use	liter	165	3500	2021
Gas Oil - Residential Heating	liter	165	1000	506
CNG - Compressed Natural Gas	m3	400	3000	650
LNG - Liquified Natural Gas	kilo	772	1800	133
Natural Gas - piped	m3	100-130	700	509
Fuel Oil - Resodential Heating	liter	98	2000	1941
Kerosene	liter	165	1000	506
Electricity	kwh	165	270	64
Subsidized Foods				
Bread (Type 1: Taftoon)	loaf	317	908	186
Bread (Type 2: Lavaash)	loaf	271	963	256
Bread (Type 3: Sangak)	loaf	322	887	176
Bread (Type 4: Barbari)	loaf	386	960	149
Eggs	dozen	200	295	47
Solid Oil	gallon	192	325	70
Suger Cubes	kilo	324	484	49
Suger	kilo	229	489	114

Table 2.2: Contents of HIES

The Major Parts		Information Provided in each Part
Part 1:	Socio-economic characteristics of households members	Urban/rural Province Age Gender Employment status (employed/unemployed/student homemaker/unemployed-but-earner/other) Marriage status (with-spouse/without-spouse due to death/without-spouse due to divorce/never-married) Literacy/illiteracy Student/non-student Educational degree (2-digits codes) Relationship to households head (head/spouse/child /groom or bride/grandchild/parent/sibling/other relative/other non-relative)
Part 2:	Ownership	Type of ownership of residence (proprietary/ leasing/provided-by-employer/free/other) Properties of the place of the residence: area, number of rooms, type and frame of construction Material used in the building of the residence Possession of a long list durables such as TV, refrigerator, car, bike, bicycle, radio, washing machine, and the likes. Access to utilities such as running water, electricity,natural gas, bath, central heater, kitchen, land-line phone,cell phone, and the likes. The main fuel used (kerosene/natural gas/gas oil/ electricity/firewood/others)
Part 3:	Expenditures	Food and drink Tobacco Clothing Housing and utility Furniture and home equipment Health Transportation Communication Cultural and leisure Informal education Hotel and restaurant Miscellaneous items Durables Investment
Part 4:	Incomes	Income from wage-and-salary jobs Income from self-employed jobs Miscellaneous sources of income

Table 2.3: Income information provided in HIES data sets

Source of Income	Information reported for each Source
Wage-and-salary-base jobs:	Job title (three-digit codes)
	The main activity at workplace (four-digit codes)
	Public sector / private sector (1/2)
	Total gross income (last month and last year)
	Net continuous income (last month and last year
	Net irregular income (last month and last year)
	Total net income (last month and last year)
Self-employed jobs:	Job title (three-digit codes)
	The main activity at workplace (four-digit codes)
	Principal / independent worker / family worker
	Agriculture / non-agriculture (1/2)
	Salaries paid to employees in the last year
	The cost of raw materials in the last year
	The amount spent for machinery and equipment in the last year
	Rent, interest and utility costs in the last year
	Total tax paid in the last year
	Gross revenue or total sale in last year
	Net revenue
Miscellaneous sources:	Pension, redemption, and the likes
	Renting all kinds of properties
	Interest received from banking accounts, bonds, stocks, and any other sources
	Transfer payments from the state or other entities for different purposes
	Selling home-made stuff

Table 2.4: Number of households in the workfile by year

Year	Number of Households
1987	1,769
1988	3,145
1989	4,335
1990	7,820
1991	9,001
1992	9,058
1993	7,305
1994	10,631
1995	17,961
1996	13,043
1997	10,864
1998	8,900
1999	11,498
2000	12,273
2001	12,268
2002	14,332
2003	11,923
2004	11,369
2005	12,528
2006	13,759
2007	14,724
2008	18,075
2009	18,762
2010	18,536
All Years	273,879

Table 2.5: Number and average size of households in total expenditure (income) groups in 2010, the year ending to the subsidy reform (monetary values are expressed per month and in units of Iranian Thousand Tomans, ITT)

Income Group	Range of Total Expenditure From	To	Number of Households	Percentage of Total	Average Size
1	0	218	1583	10	2.83
2	218	362	1584	10	3.46
3	362	448	1584	10	3.75
4	448	575	1583	10	3.85
5	575	651	1584	10	4.02
6	651	749	1583	10	4.05
7	749	891	1584	10	4.26
8	891	1094	1584	10	4.24
9	1094	1379	1583	10	4.27
10	1379	2281	1584	10	4.35
11	2281	2762	927	5	4.35
12	2762	3969	186	1	4.34

Table 2.6: Shares of aggregate expenditure spent on categories of goods and services in total expenditure (income) groups in 2010 (percent)

Income Group	SF	UF	NE	EG	S	E	H
1	12.03	25.55	6.07	0.82	9.26	3.87	42.40
2	10.94	26.08	7.65	1.35	11.25	3.89	38.84
3	10.11	26.39	8.87	1.52	11.55	3.93	37.64
4	9.59	26.64	9.88	1.79	12.48	3.93	35.68
5	8.91	26.77	10.82	2.22	13.19	4.11	33.98
6	8.42	26.29	12.53	2.81	13.21	4.01	32.72
7	7.74	26.49	13.22	3.29	13.82	4.19	31.25
8	6.74	25.87	14.70	5.33	13.64	4.30	29.42
9	5.65	24.07	15.89	9.97	13.68	4.14	26.60
10	3.99	19.65	16.53	22.36	11.97	3.66	21.83
11	3.39	17.66	17.26	26.41	11.60	3.43	20.25
12	2.57	16.90	20.29	25.76	12.60	2.85	19.03

SF: subsidized food, UF: unsubsidized food, NE: non-energy-consuming goods, EG: energy-consuming-goods, S: services, E: energy, H: housing

Table 2.7: Quadratic Engel curve regressions

Expenditure	1987-2010			2010		
Shares	_cons	ly1	ly2	_cons	ly1	ly2
Wsf	-0.4306	0.0917	-0.0036	-0.8160	0.1395	-0.0051
	(0.0341)***	(0.0040)***	(0.0001)***	(0.1577)***	(0.0183)***	(0.0005)***
Wuf	-5.2553	0.6837	-0.0210	-6.2234	0.7748	-0.0231
	(0.0764)***	(0.0090)***	(0.0003)***	(0.3364)***	(0.0391)***	(0.0011)***
Wne	-2.5618	0.2768	-0.0069	-0.5894	0.0321	0.0005
	(0.0710)***	(0.0084)***	(0.0002)***	(0.2895)**	(0.0337)	(0.0010)
Weg	10.2911	-1.2680	0.0391	12.8104	-1.5650	0.0478
	(0.0647)***	(0.0076)***	(0.0002)***	(0.3518)***	(0.0409)***	(0.0012)***
Ws	-0.9523	0.0997	-0.0022	-4.3274	0.5034	-0.0142
	(0.0506)***	(0.0060)***	(0.0002)***	(0.2442)***	(0.0284)***	(0.0008)***
We	-0.6335	0.0817	-0.0025	-0.5952	0.0737	-0.0021
	(0.0242)***	(0.0029)***	(0.0001)***	(0.1188)***	(0.0138)***	(0.0004)***
Wh	0.5424	0.0345	-0.0028	0.7410	0.0416	-0.0038
	(0.1002)***	(0.0118)***	(0.0003)***	(0.4866)	(0.0566)	(0.0016)**

Note: _cons, ly1, and ly2 indicate constant, logarithm of real total expenditure, and square of the logarithm of real total expenditure

Table 2.8: Quadratic Engel curve regressions

Expenditure	2000			1990		
Shares	_cons	ly1	ly2	_cons	ly1	ly2
Wsf	-0.1045	0.0580	-0.0028	-1.0813	0.1625	-0.0056
	(0.1682)	(0.0199)***	(0.0006)***	(0.1908)***	(0.0231)***	(0.0007)***
Wuf	-6.6256	0.8411	-0.0255	-4.0455	0.5427	-0.0168
	(0.3540)***	(0.0418)***	(0.0012)***	(0.4857)***	(0.0588)***	(0.0018)***
Wne	-2.0039	0.1996	-0.0043	-0.0816	-0.0522	0.0041
	(0.3397)***	(0.0401)***	(0.0012)***	(0.4632)	(0.0561)	(0.0017)**
Weg	10.2468	-1.2649	0.0390	3.1319	-0.4003	0.0128
	(0.3170)***	(0.0374)***	(0.0011)***	(0.2593)***	(0.0314)***	(0.0010)***
Ws	-1.1931	0.1300	-0.0032	0.7895	-0.0984	0.0033
	(0.2479)***	(0.0293)***	(0.0009)***	(0.2493)***	(0.0302)***	(0.0009)***
We	-0.3553	0.0540	-0.0018	0.2539	-0.0282	0.0009
	(0.1361)***	(0.0161)***	(0.0005)***	(0.1057)**	(0.0128)**	(0.0004)**
Wh	1.0355	-0.0179	-0.0015	2.0330	-0.1261	0.0013
	(0.4856)**	(0.0573)	(0.0017)	(0.5375)***	(0.0651)*	(0.0020)

Note: _cons, ly1, and ly2 indicate constant, logarithm of real total expenditure, and square of the logarithm of real total expenditure

Table 2.9: Demand system equations

Variables	E	SF	UF	NE	EG	S	H
E price	0.0184	–0.0086	0.0062	–0.0232	0.0045	0.0233	–0.0206
	(0.0033)‡	(0.0046)⌈	(0.0078)	(0.0061)‡	(0.0038)	(0.0059)‡	-
SF price	–0.0086	0.0464	–0.0332	–0.0311	–0.0007	0.0246	0.0026
	(0.0046)⌈	(0.0092)‡	(0.0144)†	(0.0097)‡	(0.0065)	(0.0102)‡	-
UF price	0.0062	–0.0332	0.0564	–0.0230	0.0369	–0.0095	–0.0339
	(0.0078)	(0.0144)†	(0.0326)⌈	(0.0201)	(0.0121)‡	(0.0171)	-
NE price	–0.0232	–0.0311	–0.0230	0.0488	0.0051	0.0138	0.0096
	(0.0061)‡	(0.0097)‡	(0.0201)	(0.0208)†	(0.0117)	(0.0110)	-
EG price	0.0045	–0.0007	0.0369	0.0051	–0.0076	–0.0382	–0.0001
	(0.0038)	(0.0065)	(0.0121)‡	(0.0117)	(0.0068)	(0.0060)‡	-
S price	0.0233	0.0246	–0.0095	0.0138	–0.0382	–0.0102	–0.0039
	(0.0059)‡	(0.0102)†	(0.0171)	(0.0110)	(0.0060)‡	(0.0163)	-
H price	–0.0206	0.0026	–0.0339	0.0096	–0.0001	–0.0039	0.0463
	(0.0055)‡	(0.0090)	(0.0231)	(0.0136)	(0.0088)	(0.0109)	-
ln income	0.0018	–0.0563	–0.0298	0.0553	0.0438	0.0142	–0.0288
	(0.0006)‡	(0.0012)‡	(0.0023)‡	(0.0030)‡	(0.0023)‡	(0.0014)‡	-
$(\ln \text{income})^2$	0.0000	0.0034	–0.0176	–0.0329	0.0000	0.0088	0.0384
	-	(0.0012)‡	(0.0018)‡	(0.0027)‡	-	(0.0013)‡	-
Size	0.0003	0.0104	0.0064	0.0035	–0.0040	–0.0001	–0.0165
	(0.0001)‡	(0.0002)‡	(0.0003)‡	(0.0003)‡	(0.0002)‡	(0.0002)	-
Head's sex	–0.0026	–0.0106	–0.0327	0.0050	–0.0081	–0.0046	0.0536
	(0.0003)‡	(0.0006)‡	(0.0018)‡	(0.0015)‡	(0.0006)‡	(0.0009)‡	-
Constant	0.0442	0.0609	0.2863	0.1127	0.0489	0.0961	0.3508
	(0.0010)‡	(0.0023)‡	(0.0034)‡	(0.0029)‡	(0.0024)‡	(0.0022)‡	-

Notes:
1. E: Energy, SF: subsidized food, UF: unsubsidized food, NE: non-energy-consuming goods, EG: energy-consuming-goods, S: services, H: housing.
2. The figures in the parentheses are bootstrapped standard errors based on 1500 replications.
3. ‡, †, ⌈ denote statistically significant at 99%, 95%, and 90% level.
4. Standard errors are not reported for coefficient of $(\ln \text{income})^2$ in SE and E regressions because the $(\ln \text{income})^2$ term is set to zero.

Table 2.10: Income and own price elasticities (for an urban household with average income in 2010)

Categories of goods and services	Income elasticity	Uncompensated price elasticity	Compensated price elasticity
Energy	1.04	–0.54	–0.50
Subsidized food	0.39	–0.41	–0.37
Unsubsidized food	0.78	–0.72	–0.52
Non-energy consumer goods	1.05	–0.58	–0.46
Energy consumer goods	1.85	–1.20	–1.10
Services	1.22	–1.11	–0.96
Housing	1.09	–0.89	–0.53

Table 2.11: Uncompensated cross-price elasticities (for an urban household with average income in 2010)

	E	SF	UF	NE	EG	S	H
E	–0.50	–0.18	0.19	–0.54	0.15	0.62	–0.49
SF	–0.04	–0.39	–0.18	–0.26	0.06	0.38	0.28
UF	0.25	0.11	–0.52	0.16	0.37	0.21	0.16
NE	–0.05	–0.13	–0.10	–0.47	0.18	0.24	0.16
EG	0.19	–0.07	1.04	0.08	–1.32	–1.57	–0.53
S	0.32	0.33	0.05	0.24	–0.12	–0.93	0.08
H	0.26	0.33	0.21	0.35	0.32	0.31	–0.54

E: energy, SF: subsidized food, UF: unsubsidized food, NE: non-energy consumer goods, EG: energy consumer goods, S: services, H: housing.

Table 2.12: Break down of 2010 monthly energy subsidies to urban households (monetary figures in TIT=$1)

Income group	Range of expen-ditures	Gaso-line	Gas oil 1	Gas oil 2	CNG	LNG	Natural gas	Fuel oil	Kero-sene	Elec-tricity	Total subsidy	As a % of household income
1	0–228	6.734	0.000	0.421	0.031	1.566	53.396	0.335	16.960	10.975	90.417	55
2	228–308	16.443	0.241	0.000	0.139	1.424	75.801	0.121	17.864	15.335	127.368	47
3	308–376	25.137	0.058	0.492	0.583	1.458	84.343	0.000	22.579	18.679	153.329	45
4	376–443	34.118	0.015	0.288	0.631	1.563	99.531	0.145	23.834	19.962	180.088	44
5	443–518	45.384	0.000	0.996	1.262	1.454	110.863	0.200	19.094	23.562	202.816	42
6	518–607	54.696	0.000	0.255	1.486	1.416	118.244	0.000	24.835	26.400	227.332	40
7	607–720	72.513	0.417	0.722	2.063	1.534	143.155	0.000	17.529	29.501	267.433	41
8	720–888	92.858	0.000	0.200	4.098	1.358	186.603	0.038	18.104	32.058	335.317	42
9	888–1,215	116.800	0.260	0.449	3.717	1.255	238.662	0.094	16.440	37.568	415.245	40
10	1,215–5,880	199.295	0.029	0.712	8.068	1.932	338.933	0.023	17.651	50.228	616.871	34
11	1,587–5,880	226.425	0.071	0.595	9.358	1.777	403.532	0.058	9.525	58.316	709.657	32
12	2,578–5,880	293.658	0.000	0.000	5.090	1.736	515.191	0.000	10.408	63.212	889.294	28
Average	650	59.485	0.129	0.594	1.712	2.179	155.609	0.204	28.547	30.418	278.878	43

"Gas Oil 1" and "Gas Oil 2" are gas oil for transportation use and residential heating.

Table 2.13: Breakdown of 2010 monthly food subsidies to urban households (monetary figures in TIT=$1)

Income group	Range of expen-ditures	Bread1	Bread2	Bread3	Bread4	Eggs	Solid oil	Sugar cubes	Sugar	Total subsidy	As a % of household income
1	0–228	0.786	2.564	0.408	1.594	1.000	1.654	0.784	0.356	9.145	5.6
2	228–308	1.156	4.731	0.688	1.919	1.303	2.454	1.147	0.610	14.009	5.2
3	308–376	1.541	5.055	0.721	2.109	1.506	2.900	1.401	0.814	16.046	4.7
4	376–443	1.772	5.066	1.107	1.946	1.578	3.118	1.544	0.950	17.081	4.2
5	443–518	2.043	5.324	1.024	2.184	1.696	3.183	1.784	1.212	18.449	3.8
6	518–607	1.922	5.311	1.264	2.222	1.784	3.489	1.883	1.389	19.263	3.4
7	607–720	1.824	6.228	1.496	2.201	1.915	3.475	2.131	1.506	20.776	3.1
8	720–888	1.964	6.716	1.753	2.635	2.081	3.603	2.171	1.748	22.671	2.8
9	888–1,215	2.302	7.221	1.972	3.176	2.199	3.472	2.287	1.908	24.537	2.4
10	1,215–5,880	2.670	7.924	2.482	3.135	2.584	3.731	2.570	2.387	27.484	1.5
11	1,587–5,880	2.992	8.319	3.025	3.429	2.714	3.664	2.738	2.589	29.470	1.3
12	2,578–5,880	2.100	8.015	3.041	2.818	3.383	4.858	3.596	2.943	30.754	1.0
Average	650	1.798	5.615	1.292	2.312	1.765	3.108	1.770	1.288	18.949	2.9

"Bread1", "Bread2", "Bread3", "Bread4" are types of breads called Taftoon, Lavaash, Sangak, and Barbari.

Table 2.14: Predicted break down of 2011 energy subsidies, values in ITT (Iranian Thousand Toman), 1 ITT=$1

Income Group	Percentiles	Gasoline	Gas Oil 1	Gas Oil 2	CNG	LNG	Natural Gas	Fuel Oil	Kerosene	Electricity	Sum
1	1-10	0.319	0.000	0.131	-0.003	0.509	13.667	0.025	5.273	11.682	31.602
2	11-20	0.823	0.015	0.000	-0.013	0.490	20.523	0.009	5.875	17.267	44.989
3	21-30	1.236	0.004	0.159	-0.053	0.492	22.429	0.000	7.293	20.658	52.218
4	31-40	1.654	0.001	0.092	-0.057	0.520	26.086	0.011	7.588	21.758	57.653
5	41-50	2.108	0.000	0.303	-0.109	0.463	27.841	0.014	5.825	24.609	61.055
6	51-60	2.560	0.000	0.078	-0.129	0.455	29.919	0.000	7.633	27.781	68.297
7	61-70	3.218	0.023	0.210	-0.170	0.467	34.341	0.000	5.108	29.431	72.627
8	71-80	3.931	0.000	0.056	-0.321	0.394	42.703	0.002	5.033	30.511	82.308
9	81-90	5.008	0.014	0.126	-0.295	0.369	55.325	0.006	4.629	36.218	101.401
10	91-100	9.204	0.002	0.216	-0.690	0.612	84.622	0.002	5.353	52.153	151.473
11	96-100	11.024	0.004	0.190	-0.844	0.594	106.217	0.004	3.045	63.838	184.073
12	100	16.907	0.000	0.000	-0.543	0.686	160.360	0.000	3.935	81.828	263.173
Average Household		2.591	0.007	0.170	-0.138	0.652	36.645	0.014	8.166	29.791	**77.898**

Note: "Gas Oil 1" and "Gas Oil 2" are gas oil for transportation use and residential heating, respectively.

Figure 2.15: Change in
monetary values of the subsidies (per urban household, monthly, in TIT=$1)

Income Group	Range of expenditures	Pre-reform price subsidies	Post-reform price subsidies	Direct rebates	Change in the amount of subsidies
		$S^h = S^h_e + S^h_f$	$S'^h = S'^h_e$	$A^h = n^h a$	$\Delta S^h = A^h + S'^h - S^h$
1	0–228	99.562	31.602	126.006	58.046
2	228–308	141.377	44.989	153.973	57.585
3	308–376	169.375	52.218	166.708	49.551
4	376–443	197.169	57.653	171.256	31.740
5	443–518	221.265	61.055	179.055	18.845
6	518–607	246.595	68.297	180.037	1.739
7	607–720	288.210	72.627	189.545	–26.038
8	720–888	357.987	82.308	188.592	–87.087
9	888–1,215	439.782	101.401	190.145	–148.236
10	1,215–5,880	644.355	151.473	193.565	–299.318
11	1,587–5,880	739.126	184.073	193.666	–361.387
12	2,578–5,880	920.048	263.173	193.154	–463.721
Average	650	297.827	77.898	173.888	–46.041

Figure 2.16: Equivalent variation of the change in subsidies (per urban household, monthly, in TIT=$1)

Income group	Range of expenditures	Monetary value of subsidy changes	Equivalent variation
1	0–228	58.046	60.902
2	228–308	57.585	63.098
3	308–376	49.551	59.978
4	376–443	31.740	51.541
5	443–518	18.845	45.235
6	518–607	1.739	31.765
7	607–720	–26.038	22.778
8	720–888	–87.087	–1.254
9	888–1215	–148.236	–36.896
10	1,215–5,880	–299.318	–149.870
11	1,587–5,880	–361.387	–208.417
12	2,578–5,880	–463.721	–347.191

Figure 2.17: Social equivalent variation of the change in subsidies (per urban household, monthly, in TIT=$1)

Inequality aversion index	0	0.5	1	2	5	10
Social equivalent variation	13.785	28.585	39.289	51.788	60.460	60.924

CHAPTER 3

DISTRIBUTIONAL EFFECTS OF PUBLIC SPENDING AND PROGRAMS IN IRAN

3.1 Introduction

Economic growth is often viewed as the most effective means of poverty alleviation. However, growth by itself may not be sufficient for addressing the problems of poverty and inequality.[1,2] As the debates and empirical evidence on the Kuznets hypothesis show, the growth-inequality nexus is complex and, in some situations, growth can be unequalizing (Frazer, 2006; Ferreira et al., 2010; Datt and Ravallion, 2011). Moreover, sustaining growth requires effective social protection and redistribution mechanisms that alleviate the credit and insurance market failures for the poor and help control macroeconomic and social instability risks (OECD, 2009). Thus, to better understand the growth process and to select policies more effectively, it is imperative to assess and compare the role of growth as well as public policies and household characteristics in income distribution.

The literature on economic growth, inequality, and public policy is vast. One part of this literature that focuses on the relationships among aggregate indicators has revealed the complexities of involved, but has not yet yielded clear patterns (Fosu, 2011). In addition, the use of aggregate indicators masks the details of the distributional effects of growth and policy programs. Other parts of the literature are concerned with evaluating the impact of various social protection programs on their targeted groups through surveys or experimental and pilot projects. However, these studies typically deal with individual programs and do not show how they compare and interact with other programs and factors. Moreover, these micro studies rarely take

[1]This is a joint work with Prof. Hadi Salehi Esfahani

[2]For overviews of the large literature on growth, distribution, and poverty, see, for example: Ames et al. (2001), Dollar and Kraay (2002), World Bank (2001, 2004, and 2006), Fosu (2010), and Ravallion (2010, 2012).

account of the indirect and general equilibrium effects of public programs on the population at large (see Angelucci and De Giorgi, 2009, for a rare exception). In this paper, I use quantile regression method and micro data from Iran to estimate the broad effects of various social programs, government spending, economic growth, and household characteristics, on different quantiles of the expenditure distribution. I also apply the decomposition technique of Machado and Mata (2005) to assess the role of these factors on the 1998-2005 trends in household expenditure distribution. It should be pointed out that my focus in this paper is the direct effects of policy indicators on household expenditure, taking the trends in household characteristics as given. To the extent that the policies influence household characteristics, there are indirect effects that call for a much more extensive model. I leave that exercise for future research.

The case of Iran is interesting because in recent decades the country has experimented with new arrangements for addressing poverty concerns and has been relatively successful in this regard. In fact, the head count poverty rate in Iran declined robustly from about 40 percent in 1989 to well below 10 percent in the mid-2000s (Salehi-Isfahani, 2009). This trend was partly driven by economic growth and partly by other factors such as large food and fuel subsidies, improved access to education and infrastructure, and expanded welfare services by the government, public foundations, and non-government organizations (Esfahani, 2005; Abounouri and Khoshkar, 2008; Salehi-Isfahani, 2009). Changes in household characteristics, especially due to reduced fertility, are also likely to have influenced expenditure distribution. However, little is known about the effectiveness and the relative importance of such channels.

Of particular interest for policy purposes is the assessment of welfare and social security bureaucracies (Social Welfare Organization, SWO, and Social Security Organization, SSO) and Imam Khomeini Relief Foundation (IKRF). SWO is part of the Ministry of Welfare and Social Security. SSO is also supervised by that Ministry, but it acts as an autonomous organization financed by its investments and member contributions. IKRF, on the other hand, is a public foundation that receives public funding to address poverty, but has its own assets and operates independently of the government bureaucracy under the auspices of Irans Supreme Leader. These three organizations have different missions, but their activities overlap in some areas. All three organizations are believed to have major distributional consequences since they are large and each manages substantial resources. Yet, the effects of their programs on household expenditures have never been quantitatively assessed in ways that could be compared across programs or with other factors such as economic growth, government spending, and changes in household structure. This is the task that I take up in this paper.

Endogeneity of policy variables poses a challenge for my analysis, particularly in the context of quantile regressions, which are computationally very demanding. In fact, there is currently no quantile regression package that can handle more than one endogenous variable and yield reliable estimates. I address this problem by employing a two-stage process that produces consistent point estimates, but may yield inconsistent standard errors. I argue that the main results of the analysis are reasonably reliable because the biases in standard errors are likely to be relatively small. I provide support for this claim by comparing the results of the two-stage and full estimation procedures using restricted models that have only one endogenous variable. The rest of this paper is organized as follows. In section 2, I review the relevant literature on poverty reduction and highlight the contributions of this paper. In section 3, I discuss the poverty trends and the social protection system in Iran and place them in the countrys political economy context. Section 4 describes the data. Section 5 provides an overview of the trends in the macroeconomy, the social spending, and the household expenditure quantiles. Section 6 describes the quantile regression model and presents and analyzes the results. In section 8, I decompose the shifts in the household expenditure distribution to assess the role of various factors in the trends during 1998-2005. Section 9 concludes.

3.2 An Overview of the Related Literature

The vast literature on economic growth, inequality, and public policy has many sub-areas. One area focuses on measuring the changes in poverty rates and decomposes them into growth and redistribution components (see, for example, Foster et al, 1983; Maasoumi, 1986; Ravallion, 2004). The decomposition is useful, but it does not establish the sources of the shifts in the position and shape of the expenditure distribution. Indeed, many of the underlying factors may simultaneously affect both growth and redistribution.

Another major part of the literature on poverty has dealt with program evaluation. These studies typically estimate the effects of specific poverty relief programs on the targeted individuals, using untreated groups as controls. A prime example of the programs under study is the widely debated conditional cash transfers (CCT) and their comparison with the unconditional transfers. CCT programs have been found effective in many cases such as support for poor households that ensure their children attend school or received needed vaccinations. However, the outcome depends crucially on the supply of pertinent infrastructure and public services.[3] In the absence of such complimentary services, CCTs have little impact on poor households investment in their childrens health and education (de Janvry and Sadoulet, 2005). Examples are households in the remote, war-torn, or disaster-struck areas. Also, CCTs are often harder to design for poor households with no children or those with disabilities and disadvantages that impede their access to such programs (Das et al., 2005; de la Brire and Rawlings, 2006). Schubert and Slater (2006) further argue that the full costs and benefits of conditionality are often difficult to assess, especially when the country lacks the institutional capability to execute the program efficiently. In such cases, unconditional transfers may work more effectively. Coady et al (2006) review of the lessons and experiences of targeting attempts extensively and conclude that implementation details matter tremendously in the performance of CCT programs.

Given the limitation of CCT programs, providing safety nets and targeting them on the most vulnerable groups is often done via means testing (i.e., conditioning support on the individuals socio-economic characteristics). The success of means testing hinges on the setup of the program, the quality of the collected data, and the efficacy of administrative and networking infrastruc-

[3]See, for example, Berhman and Hoddinott (2001) and Shultz (2003) show that Mexicos Progresa program has had positive impact on child growth and school attainment. Bourguignon et al. (2002) and Cardoso and Souza (2003) find that Brazils Bolsa Escola has had positive effects on school enrollment, especially for poor households. Bourguignon et al. (2002) further demonstrate that child labor and school attendance are not influenced by alternative UCT programs. Khandker et al. (2003) study Bangladeshs Female Stipend Program, finding positive educational effects, especially among girls. Studying another CCT program executed in Bangladesh, Food for Education, Ravallion and Wodon (1999) show favorable effects on schooling and child labor. Similarly, Miguel and Kremer (2004) demonstrate that Kenyas Deworming Project has increased school attendance.

ture.[4] Means testing seems to have contributed to the success of Brazils Bolsa Familia and Mexicos Progresa. But, little is known about the conditions under which it can work in other contexts. Research on the match between the setup of the social protection programs and the institutional context in which they operate is still at early stages. Since Irans social protection programs are generally based on means testing, the results could shed light on how well each one fits its institutional settings. The literature on program evaluation has mostly focused on the impact of transfers and conditions on the targeted groups, treating the indirect and general equilibrium effects (e.g., through inter-personal transfers and relative price changes) as secondary. However, in many developing countries, where institutions are weak and market failures abound, transfers are likely to have major indirect effects on household members, relatives, acquaintances, and community members. In addition, slow supply response and limitations of trade and market integration often lead to price changes that could affect the real expenditures of the transfer recipients as well as others in the economy. This particularly matters for large, country-level programs. Therefore, in order to account for such general equilibrium effects, the impact of the program on the entire population needs to be assessed. But, this has often been overlooked. A notable exception is the work of Angelucci and De Giorgi (2009), who takes advantage of the experimental data on the treated and untreated households in Mexican villages where Progresa has been implemented. They show that the program led to higher loans and transfers to family and friends, raising the food consumption of untreated households by about 10%. This effect is quite sizable since the increase in the food consumption of the treated households is about 20%.

The broad effects of policies on income distribution and poverty have been the subject of two other lines of study. The first line has examined the consequences of growth and major policy shifts on the summary indicators of household expenditure distribution, such as the poverty rate, quintile shares, and the Gini coefficient. For example, Adams (2004) estimates the growth elasticity of poverty rate using 126 surveys from 60 countries. Another example is Datt and Ravallion (2011), who build aggregate indices based on 50 years of household surveys in India to assess the impact of economic growth

[4] See Samson et al. (2006) and Samson (2009) for more details about the design of such programs.

and policy reforms on expenditure distribution in the country. They find that growth has generally helped reduce poverty, though it has been associated with increased inequality since the start of economic policy reforms in 1991. Similarly, Ferreira et al. (2010) measure the elasticity of poverty with respect to growth in Brazil, over time and across sectors and locations. Their results show that the growth-poverty relationship has varied across situations, but on the whole, growth has played a small role in poverty reduction. Rather, the improvement has been due to the taming of hyperinflation in 1994 and to the expansions in social security and social assistance transfers. Yet another example is a series of papers from Garuda (2000) to Oberdabernig (2013) that examine the effects of IMF programs on poverty and distributional indicators. In the case of Iran, Abounouri and Khoshkar (2008) examine the role of employment, inflation, and the governments tax revenue and social expenditure on the Gini Coefficient and the shares of different quintiles, using time series methods. They find that employment and social expenditure are associated with less inequality, lower shares of the top quintile, and higher shares of the bottom 60 percent. The exact opposite is found for the association of the distributional indicators with inflation tax revenue. None of these studies control for the variations in household characteristics.

The second line of research on the broad consequences of policies has taken a more detailed modeling approach, typically in the form of simulation via computable general equilibrium (CGE) models. Among the earliest use of CGE models with representative households to evaluate distributional impact of economic policies are Adelman and Robinson (1978), Dervis et al. (1982), and Gunning (1983). Later generation of CGE models included micro submodels to take fuller account of the distributional effects. However, CGE models depend on a myriad of detailed assumptions and require immense amounts of data, hampering their reliable application, especially in the case of developing countries.

Over the past decade and a half, the conditional quantile regression method, pioneered by Koenker and Bassett (1978), has come to be recognized as an important tool for assessing the impact of various factors on the entire distribution, allowing for the effects to vary according to the position of each individual in the distribution. This method has been applied to a variety of issues concerning inequality, especially in the case of wage and firm size distribution.[5] This literature mainly focuses on how changes in the distribution of individual characteristics have shaped the shifts in outcome distributions.

In this paper, I use a quantile regression to estimate the effects of household characteristics as well as economic growth and policy factors on the sample of households included in the yearly household expenditure surveys in Iran. I take advantage of the data at the province level to enhance the amount of information on government and social program spending. The dependent variable in my model is household-level real expenditures, which is regressed on province level growth and policy variables, controlling for a battery of relevant household characteristics. Adding year and province fixed effects help deal with cross-sectional dependence and many unobservable factors.

3.3 Poverty Reduction, Social Protection, and Political Institutions in Iran

Irans 1979 revolution was based on a mass movement led by a charismatic figure, Ayatollah Khomeini. The process was facilitated by the activities of many small groups that were ideologically diverse and organizationally fragmented. However, almost all of them shared two key objectives. First, they opposed the Shahs authoritarian regime and its Western-oriented social and economic policies. Second, they resented the increased inequality under the Shah and favored redistribution and pro-poor policies. Although many of these organizations were wiped out in the power struggle that ensued after the revolution, the ideal of redistribution and poverty reduction remained a core principle of the new regime. Accordingly, the existing public organizations engaged in social protection were reshaped and reoriented and new ones were formed to address this objective.

The private and public foundations and NGOs that engage in various social support activities in Iran are numerous. Many of them are relatively small and are not focused on poverty alleviation or redistribution per se. For example, a number of public foundations support war veterans and the families of martyrs. Some foundations, including the sizable Astan Quds Razavi, are

[5] See for example, Machado and Mata (2000 and 2005), Autor, Katz, and Kearney (2008), and Firpo, Fortin, and Lemieux (2007). Lemieux (2010) provides a recent survey of the wage inequality literature.

committed to religious and cultural goals. Most NGOs pursue causes such as support for cancer patients or for children or women in difficult circumstances. Many of the private entities that mainly deal with poverty issues are the traditional charity organizations, which are numerous and largely informal (Bahramitash, 2013). The main public foundation that dominates the poverty alleviation activities is IKRF, which I include in the analysis below. Unfortunately, there is very limited data on other foundations, NGOs, and charities to allow to assess as part of my estimations.

IKRF has its roots as a clandestine organization in support of families of religious political prisoners before the Islamic Revolution. It was led by a group of bazaar merchants and clergymen, who were follower of Ayatollah Khomeini. They developed a strong network to solicit funds for their cause, to identify the prisoners families and their needs, and to deliver the necessary support to them. Shortly after the Revolution, the leaders of the organization decided to expand their network and use it for addressing poverty issues. They established IKRF as a public organization under the supervision of the Office of Supreme Leader. Since in Irans political structure, the Supreme Leader is above all branches of the government, this setup allowed IKRF to receive funding and assets from the government, while enjoying a high degree of autonomy. The legislation establishing IKRF gives it a broad mission that includes: designing and implementing strategies to eliminate different aspects of poverty; providing the livelihood needs of the poor; enabling the poor to be self-reliant; offering insurance, legal consulting, counseling, pension, credit, education, and cultural services; and mobilizing private funds to support its activities and to promote the culture of private donation. It was also put in charge of the Rajaii Program, which was designed to offer pension to the elderly poor. This program was initially meant to target those in rural areas, but it was soon extended to urban areas as well. IKRF quickly expanded its network all around the country. By the 1990s, it covered, directly or indirectly, all cities, towns, and villages. In 2009, it operated 1365 units with 14,827 full-time employees and 117,957 part-time workers and volunteers.

The role of IKRF in Iran has been controversial (see Esfahani, 2005; Harris, 2012a). Critiques have argued that its autonomy from the executive makes it less accountable to the public. They have also claimed that it takes a traditional charity approach to poverty alleviation. In particular, some politicians and policy analysts in Irans Reformist movement used to view

NGOs as more effective mechanisms for social protection and tried to shift SWOs budget towards them, partly taking government funding away from IKRF. In addition, IKRF has been accused of using its resources for political purposes, mustering support for the conservative groups associated with its leadership. However, others have pointed to IKRFs potentials for fulfilling its mission. In particular, IKRFs autonomy gives it important institutional advantages. First, IKRF can avoid the rigidity of the government bureaucracy and act flexibly in the face of complexities involved in dealing with poverty cases. Second, it can act fast in response to unforeseen events and natural disasters because it controls its own budget and has assets to use if necessary. Third, IKRF can plan and invest in its activities on a long-term basis because it is relatively insulated from the policy swings induced by the political cycles in the executive and legislative branches. Finally, IKRF has changed its approach to poverty alleviation since its earlier years, moving towards enabling services that deal more comprehensively with the sources of each households poverty. Despite these very contrasting views of IKRF activities, there has been little quantitative research on its performance (see Esfahani, 2005, for a first effort in this direction). The statistical analysis in this paper is an attempt to fill this gap.

In addition to IKRF, I focus on two government-run organizations that have major consequences for poverty alleviation and redistribution. The first one, SWO, manages a host of social protection programs dealing with poverty as well as disabilities, addiction, and personal and social traumas. As such, SWOs responsibilities go beyond poverty alleviation, but all its activities have clear consequences for reducing the risk of poverty for households in adverse conditions. SWO was initially formed as part of the Ministry of Health and then move to the Ministry of Welfare and Social Security. Its budget is set annually as part of the supervising ministrys allocations. The second organization, SSO, operates as an autonomous public corporation and offers pension plans and medical and unemployment insurance. It was initially attached to the Ministry of Labor and mostly covered formal sector workers and fixed-term government employees. Overtime, it has expanded its offering of optional insurance to many independent private-sector workers. SSO operations do not target the poor. Rather, they provide insurance and expenditure smoothing that should help a large part of the labor force employed in the formal sector of the economy. For this reason, SSO is likely to have most impact lifting up the household welfare broadly, except perhaps at the top and bottom of income distribution. [Harris (2012b) offers a detailed discussion of the activities of SSO]. The question is how much SWO, SSO, and IKRF activities contribute to the real incomes of various groups in the population.

The relative coverage of IKRF, SWO, SSO, and NGOs can be seen in Figure 3.1 along with the poverty rate in Iran. As the figure shows, the poverty rates in the late 1980s were very high. In the early 1990s, as the economy recovered from the war with Iraq, the poverty rate rapidly declined. At the same time, all three main welfare organizations started to expand quickly. SWOs coverage rate soon stabilized at the rate of 10 people per 100 households. The coverage rates of SSO and IKRF, on the other hand, reached their plateaus in the late 1990s. In recent years, SSOs coverage has begun to grow rapidly, while IKRFs has declined somewhat. It is clear from Figure 3.1 that SSO is the largest among the three by the number of individuals that it serves. Figure 3.1 further shows that IKRF has a much larger coverage than SWO, by a factor of four. The data for the coverage of NGOs starts in 2001, after SWO shifted part of its budget and some of its tasks toward them, following the policies of the reformist government of President Khatami. Indeed, as Figure 3.1 shows, the NGO coverage rate basically matches the decline in SWO coverage rate after 2001. For this reason, to assess the impact of SWO, it makes sense to include NGOs in its coverage rate. This is what I do in the econometric analysis below. I will also note the consequence of combining SWO and NGO coverage rates for the results.

A major driver of real incomes and their distribution in Iran is government expenditures and subsidies. In particular, food and fuel subsidies were large and had major consequences for households, at least until 2011. However, since these subsidies were in the form of price controls, they were not shown in the government budget data.[6] In this study, the role of such expenditures, which were uniformly offered to all provinces, will be captured by the year and province fixed effects. The same applies to other country-wide expenditures. The remainder, which is the budget allocated to provinces, will be used in the analysis to gauge how such public spending has shaped the distribution

[6]Esfahani and Taheripour (2002) show that during the 1980s and 1990s such implicit subsidies were quite large, amounting to about 25-30 percent of GDP.

of household expenditures. The data on province-level government spending end in 2006, when the government restructured its budgeting system and dismantled the Plan and Budget Organization to give the President a free hand in managing the budget. The government even stopped publishing the details of its budget data after 2008. For the period when data are available, the size of province-level government spending has been about an order of magnitude larger than that of IKRF (see Figure 3.2).

3.4 The Data

The main source of the data is the annual Household Expenditure and Income Surveys (HEIS) carried out by the Statistical Center of Iran. The data is available from 1984 onward. However, for the statistical analysis, I focus on the 1991-2006 period for four reasons. First, IKRF and SWO data are not available for the years before 1991. Second, the process of establishment of the revolutionary government and the war in the 1980s made the circumstances in those years very different from the post-1990 period. Third, the quality of the data from the 1980s is lower than in the later years. Fourth, government spending classifications changed substantially after 2006 when the government reorganized the fiscal process.

HEIS collects data on household characteristics along the details of income and expenditure information. The number of households included in the 1991-2006 surveys has been generally increasing over time, ranging from 18,671 in 1992 to 32152 in 2002. The target population includes all private and collective settled households in urban and rural areas. HEIS uses a three-stage, cluster sampling method with strata. At the first stage, the census areas are classified and selected. At the second stage, the urban and rural blocks are selected, and at the final stage, households are sampled. The number of samples is optimized to estimate average annual income and expenditure of the sample household based on the aim of the survey. In order to obtain samples that are more representative of the whole year, the administration of the surveys is spread evenly over the twelve months.

I use the country-wide consumer price index (CPI) to estimate the real values of all nominal expenditures. To correct for CPI differences across provinces and between urban and rural areas, I employ province and urban dummy variables in the regressions. I calculate the total household expenditure of each household by summing up all expenditure items, except investment spending.

The data regarding on IKRF's activities and spending is available from IKRF Statistical Report (various years). Part of this data is also included in the Statistical Yearbook of Iran, published annually by the Statistical Center of Iran and placed on its website, www.amar.org.ir. This Yearbook is also the source of province-level data on SWO, NGO, and SSO activities and on CPI and government current and development spending. For SWO, NGOs, and SSO, the Yearbook provides only the number of people covered by the activities of each in each province in each year. I scale all these province-level variables by the number of households in each province to make them comparable across provinces. The data on the number of households and population in provinces is available from the General Census of Population and Housing (various years), published by the Statistical Center of Iran.

There are two issues concerning the SSO data that need to be highlighted. While the Yearbook offers information on a number of different insurance schemes offered by the SSO, the extent of details and the categories reported change over time. I deal with this issue by defining three broad categories of beneficiaries that encompass all those covered: Mandatory coverage (those whose employment by law requires them to be part of SSO pension and healthcare plans), optional coverage (those who have the option to take advantage of the SSO insurance schemes, such as self-employed workers in fields of activity specified by law), and unemployment coverage (those who benefit from SSOs unemployment insurance).

The second issue regarding SSO data is that for 1993-1995, the Yearbook gives the number of workers covered by unemployment insurance only at the country level. I use the aggregate numbers and the shares of covered workers in each province in 1992 and 1996 to interpolate the data for 1993-1995. I will discuss the caveats concerning this interpolation in section 6. In 1990, Iran had 24 provinces, including the capital district, Tehran. Overtime, some provinces have been divided into smaller ones. Also, occasionally some counties have been separated from one province and attached to another one. To deal with these shifts, I focused on the original 24 provinces and aggregated and adjusted the data appropriately to produce a consistent and balanced panel of province-level data during 1991-2006. These 384 province-year cells contain a total of 386,994 household observations. In the quantile regressions, the starting year is 1993 and the number of observations declined to 349,651 households over 336 province-year cells because I instrument government and welfare program spendings with their second lagged values.

Table 3.1 presents the summary statistics of the variables used in the regressions. Note that the average number of households per province-year is 1041, but its minimum is 36, which is quite small. However, there are only four provinces that have sample sizes less than 100 they all belong to 1993. Dropping the observations from those provinces or all of 1993 data does not change the results in any tangible way.

3.5 Public Spending and Personal Expenditure Growth and Distribution

In this section, I provide an overview of the key trends in the government and welfare agency spending as well as in poverty rate and individual expenditure patterns. For calculating poverty rates, I estimate individual expenditure based on household spending, using the square root of household size as the scale. (Using other scaling methods such as household size or its log does not change the observed trends or the main conclusions here.)

Figure 3.2 shows the trend in the country-wide, real mean and median individual expenditures, along with the real per capita spending of the government and IKRF at the province-level since 1984. IKRF spending at the national level is essentially the sum of its province level spending plus its central office expenses. The governments total expenditure is much larger than the amounts that it allocates for province-level spending (about 5-6 times). The difference is the cost of central administration, defense, national projects, and subsidies. However, the trends in the national- and province-level public expenditures are very similar.

Figure 3.3 presents the trends in some key quantiles of the individual expenditure distribution. Figure 3.4 further highlights the way in which the key bottom quantiles have been moving relative to the median. As the trends in Figures 3.3 and 4 clearly show, Irans economic conditions were deteriorating fast during 1984-1989 period due to the destructive war with Iraq, which ended in 1988. This was initially associated with deterioration in the relative position of the lower income groups during 1984-1986. However, as the economy plunged further in 1987-1988, the governments rationing and distribution policies protected the very poor at the cost of the richer households. After the war, the government launched a set of reconstruction and liberalization policies that helped the economy quickly bounce back during 1989-1993 (Figure 3.3). Although the initial benefits went largely to the middle and upper income groups, this was reversed in 1992-1993 and the poor regained their relative positions (Figure 3.4). However, in 1994, low oil revenues and some difficulties encountered in the liberalization process led to a foreign debt crisis, followed by severe a stagflation episode that was treated through austerity measures. As a result, mean and median private consumption stagnated until around 1997, when the government managed to address the debt problem. After 1998, oil revenues began to rise. Also, the reformist government that was in office during 1997-2005 lifted the austerity measures adopted in 1994 and implemented a series of market-oriented policies. These factors allowed the economy to expand steadily until 2007.

The growth rates of mean and median individual expenditures during 1990-2007 were 3.5 percent and 3.4 percent per year, respectively. Real government and IKRF grew even faster in those years, especially in the early 1990s, and registered average growth rates of 6.4 percent and 15.0 percent, respectively. Until 2003, this process, on the whole, favored the poor relative to the median and the rich. But, there was a significant reversal during 2003-2006. Although expenditures grew across the spectrum, the relative positions of the poor deteriorated, especially those in the second and third deciles. As Figure 3.4 shows, the impact of these fluctuations on the relative expenditures of those in the first decile was much milder, probably as a result of the operation of the countrys social safety nets for the very low income groups.

The new administration that took office in 2005 engaged in a massive redistribution from the top deciles towards the bottom ones, while stimulating the economy strongly to maintain the pace of growth. The redistribution did raise the relative expenditures of the lower quantiles for a while (Figure 3.4), but the policy proved highly inflationary. The government then had to adopt contractionary policies, causing a recession during 2008-2009 (Figure 3.3). A decline in oil revenues in those years may have also contributed to the process, although it did not cause any depreciation of the exchange rate. Indeed, the nominal exchange rate was kept constant and the real exchange rate of the Iranian rial was allowed to appreciate significantly in those years.

The economy briefly recovered in 2010, but encountered a significant stagflation in 2011-2012 due to a combination of factors. One factor was the tightening of international sanctions on Iran. However, domestic expansionary policies were also responsible. In particular, the government had engaged in a monumental housing project and in December 2010 launched a major subsidy reform programs. Both projects contributed to huge budget deficits. The subsidy reform was initially sold as program that could help government finances by raising energy and food prices substantially, redistributing half of the proceeds as cash across the entire population, and using the rest to develop infrastructure and to support industries adjust to the energy price shock. However, the realized proceeds fell far short of the cash transfers. This miscalculation not only ruled out the planned support for industries and infrastructure, it led to significant deficit spending and ultimately to high inflation. The policy seems to have redistributed incomes in favor of the poor for a while. But, the value of the cash transfer was quickly eroded and the governments effort to contain inflation seems to have deepened the recession and unemployment problems that particularly hurt the poor.

I are interested in assessing the impact of economic growth and various forms of public spending on the level and distribution of household expenditures. In particular, I would like to know how these factors have affected the incomes of the poor in Iran. One way to perform this task is to estimate a model that relates the mean and some benchmark quantiles of expenditure to those variables. In essence, this approach is similar to the typical growth models, with expenditure quantiles replacing per capita income. A difficulty with this approach is that it makes no use of the available information about the characteristics of households in shaping the distribution. One can, of course, include summary measures of the distributions of household characteristics in the regression. But, that technique may not capture the connections between the households characteristics and their places in the distribution. This is important because those characteristics matter not just for determining household expenditures, but they also influence the way policies affect the expenditure distribution. Indeed, government programs typically target households directly or indirectly based on their characteristics. Quantile regression method, which I discuss and apply in the next section, offers a way to deal with these concerns.

3.6 A Quantile Model of Household Expenditure, Growth, and Public Spending

In this section, I first describe the quantile regression that I use in the analysis. I then present the estimation results. The dependent variable of the model is the real expenditure of household i in province p in year t, E_{ipt}, which is assumed to be distributed as $F_E(r) = Pr(E_{ipt} \leq r)$. The τ^{th} quantile of E_{ipt} is given by $Q_E(\tau) = F_E^{-1}(\tau) = inf\{r : F_E(r) \geq \tau\}$. The real expenditure of household i depends on the vector of its characteristics, X_{ipt}, and the vector of province conditions, Y_{pt}, including public spending and social protection programs. However, the relationship may vary depending on the position of the household in the expenditure distribution. For example, IKRF spending is expected to be consequential for the expenditures at the lower tail of the distribution much more than elsewhere. If the relationships can be treated as linear and if household i is at quantile τ, I can write

$$E_{ipt} = X'_{ipt}.\alpha(\tau) + Y'_{ipt}.\beta(\tau) + \varepsilon_{ipt}(\tau)$$

where $\varepsilon_{ipt}(\tau)$ is a random variable whose τ^{th} quantile is zero: $Q_E(\varepsilon) = 0$. This means that the τ^{th} quantile of E_{ipt} can be expressed as: $Q_E(\tau) = X'_{ipt}.\alpha(\tau) + Y'_{ipt}.\beta(\tau)$. I use bootstrapping to calculate the standard errors. Also, to take account of the possible interdependence of the observations, especially within each province in each year, I use a cluster approach.

There are many household characteristics that can be included in X_{ipt}. Most obviously, expenditure should rise with the size of the household. To take account of this factor, I first created a set of dummies for household sizes 1, 2, , 12, and 13 and more and included them in the regressions.[7] I then checked the coefficients of these dummies against various functions of household size. The pattern of coefficients came closest to the log of household size plus one, which I selected as a summary measure and used it in the regressions to avoid the dimension of the parameter space getting too big.

For other household characteristics, I selected a set of variables that I believed to be important and proved statistically significant inthe regressions.

[7] Household sizes above 13 are rare and having additional dummies for them does not change the conclusion.

I carried out a number of experiments with larger sets of household variables to check the sensitivity of the results with respect to this aspect of specification. The main results regarding public policy variables proved robust to such variations. In the end, I limited the number of household characteristics to ensure estimation parsimony and to avoid multicollinearity and endogeneity as much as possible. The characteristics that I ultimately selected are as follows:

> *Age of Head of Household:* Household income and, therefore, its expenditure are likely to be lower for households headed by very young or very old individuals. Therefore, I included the age of head of household and its square on the right-hand side of the regression. I expect the coefficient of the linear term to be positive and the coefficient of the square term to be negative. Since higher income households are typically in a better position to smooth their consumption over their lifetimes, the age effect on expenditure should be weaker for them. In other words, I should see much larger effects of the age variable and its square for the lower quantiles of the distribution.
>
> *Female Headed Household:* This is a dummy variable that equals 1 if the head of household i is female and it is 0 otherwise. Since women generally tend to earn less than men of similar age and education, the coefficient of this variable is expected to be negative for the entire distribution. However, it is likely to have a larger magnitude for the households in lower quantiles because womens disadvantages are often exacerbated when they are among lower income social strata.
>
> *Education of Non-Student Adults in the Household:* Education is typically associated with higher earning and expenditure capabilities. As a summery measure that takes account of the diminishing effect of the earning potential of all household members education, I use the log of the total years of education of non-students adults in the household. The coefficient of this variable is expected to be positive for the entire distribution. The effect is likely to be larger for the lower expenditure quantiles because they are likely to have fewer other assets and, thus, can experience a bigger percentage change in their expenditures for a given rise in their education.

Young Children in Household: Log of one plus the number of children aged less than 16 years in the household i. This variable has been added to take account of the fact that, given household size, children tend to have lower expenditures than adults. It is difficult to tell ex ante how this effect changes among different expenditure quantiles.

Teenagers in Household: Log of one plus the number of persons aged 16 to 19 years in the household. The inclusion of this variable is meant to take account of the possibly larger amounts that household may spend for teenagers. This is a major consideration in Iran where many households recruit tutors for their teenagers to prepare them for the university entrance examinations. Based on this view, the effect is likely to be larger among upper quantiles of expenditure.

Elderly in Household: Log of one plus the number of anyone aged 65 years or more living in the household, other than the head of household and his/her spouse. The elderly may add to household expenditures due to their higher support and healthcare needs. They may also own some assets of their own to contribute to the household expenditures. As a result, their presence is likely to raise expenditure. It is difficult to say a priori whether this effect rises or declines with household expenditure quantiles.

Urban Dummy: Equals 1 if household i resides in urban areas and 0 otherwise. I expect the coefficient of this dummy to be positive and higher for the lower quantiles of expenditure. The latter hypothesis is based on the view that lower income households in rural areas face much bigger obstacles taking advantage of income generating opportunities in urban areas, while high income households are better connected with urban areas and benefit more from trade with urban areas.

I account for the role of economic growth in household expenditures by including in Y_{pt} the per capita real expenditure in each province. To control for the initial conditions and the remaining fixed characteristics of each province, I use province fixe effect. Also, to capture the role of countrywide factors over time, I use year dummies.

Policy variables that potentially influence household expenditures a given locality and year certainly include the activities of the government, IKRF, SWO, NGOs, and SSO. For government activity level, I use the log of per household spending in the province. For IKRF, I have data on both spending and coverage per household for its various activities. Experimenting with various combinations of these measures, I found only the log of total spending per household and the log of the number of Rajaii Program beneficiaries per household in the province to be significant for some range of the household expenditure distribution. In case of SWO and NGOs, I only have data on total number of beneficiaries in each province. I combined the numbers for SWO and NGOs and calculate the log of the ratio of the total to the number of households as measure of the SWO+NGO coverage. Finally, for the SSO I use the log of the number of beneficiaries of mandatory, optional, and unemployment coverage scaled by the number of households in the province.

One key concern about public program activities is that they are endogenous. For example, IKRF spending is supposed to rise when poverty rises, thus inducing a positive correlation between the two. As a result, if I do not address this issue, the estimated coefficients may seem to indicate that IKRF spending reduces the economic conditions of the poor. The best way to deal with this problem is to employ instrumental variables (IV). A common option for this purpose, which I adopt, is to use the lagged values of endogenous variables.

IV quantile regression (IVQR) procedures are computationally very demanding and the statistical packages currently available for estimating IVQR handle a only one endogenous variable.[8] In fact, the packages often fail to yield results when there is more than one endogenous variable and a few exogenous ones. This limitation precluded the use of such packages for the full model. Instead, I followed a two-pronged approach. For the main model, I used a two-step method, first predicting the values of the endogenous variables based on their lagged values, and then including the predicted values as regressors in quantile regressions. Although I calculated robust standard errors, this procedure may yield inconsistent confidence intervals. Gauging the extent of this potential bias is the second prong of the approach. To this end, I experimented with abbreviated versions of the model, keeping one

[8]There are two Stata procedures that employ IV quantile regression. One of them, *ivqte*, is strictly for a single endogenous treatment effect (0-1 variables). The other, *ivqreg*, contributed by Do Wan Kwak, allows for two endogenous variables, but it is still in the development process and has many limitations. It can be found at: http://faculty.chicagobooth.edu/christian.hansen/research/ivqrstata.zip.

endogenous variable and a set of other regressors. For every endogenous variable, I estimated the abbreviated model in two ways: (1) using the two-step procedure as in the full model and (2) using the Stata code, *ivqreg*, which yields consistent estimates. I trimmed the set of regressors until the *ivqreg* procedure resulted in coefficient and standard error estimates. Comparing the results obtained in these two ways helped me assess the extent of the bias caused by the two step procedure. (The *ivqreg* results are not presented here to keep the length of this paper manageable.) I found that the bias is generally small such that the main conclusions are not affected. Based on these results, I concluded that the bias in the full model estimates is likely to be limited.

Another concern about the policy variables is that their role may have changed over time. In particular, with the political turnover in the executive and the legislature in 1997 and 1998, it is possible that the role of government spending or the activities of IKRF, SSO, and SWO may have shifted. Another possibility is that each programs effect may have changed as they matured in the 1990s. For SWO unemployment coverage variable, there is an additional concern that interpolation data for the 1993-1995 may affect the results. To address these concerns, I entered economic growth and each of the public program variables during the entire period along with their interactions with a dummy for the 1993-1997 period to capture coefficient differences that may have prevailed before 1998. I did the same for household characteristics. However, for the latter set of variables the differences were virtually zero for the pre-1998 period. So, for the sake of parsimony, I did not include the interaction terms for the household characteristics in the results that I report below. I also examined the stability of the coefficients of within each sub-period by shifting the start and end of the period by a couple of years. (The length of each period could not be too short because I use province and year fixed effects and the estimates of policy variables are based on their variations across provinces and over time.) These experiments showed that the estimates are reasonably robust. Hence, to ensure sufficient degrees of freedom in estimating the effects of policy variables, I did not breakdown the sub-periods further.

3.7 Quantile Regression Results

The results of the quantile regressions are shown in Figures 3.5–3.14. Figure 3.5 shows the effect of economic growth on the distribution of household expenditure. The left-hand-side panel is the graph of the marginal effect of one percent increase in economic growth on the log of household expenditures at different parts of the distribution. The estimates are quite precise and steadily rise from 0.7 for the poorest 5th percentile to about 1 for the 95th percentile. The right-hand-side graph shows that the unequalizing effect of growth may have been stronger during 1993-1997, significantly so for the bottom 10 percent and the top 20 percent. The differential effects on the rich and the poor in both periods are indeed large and mean that while the economic growth in Iran has been lifting all household expenditures, it has had a strongly unequalizing effect. However, as I will see below, this gap has been filled for the poor by economic policy and changes in household characteristics.

Figure 3.6 shows that the marginal effect of province-level government spending has been positive and strong on the bottom quintile, though only after 1998. The effect for the rest of households is virtually zero both before and after 1998. The effects of IKRFs expenditures, on the other hand, have gone further and reached the bottom 70 percent of the population before 1998 and the bottom 60 percent afterwards (Figure 3.7). The estimated effects of IKRF spending are quite high for the very poor and decline as income rises. The finding that the effect for the middle 40 percent had been stronger before 1998 is interesting because the Iranian economy had gone through a crisis during 1993-1997 and it seems that IKRF had kept its net wider at that time. In contrast, according to Figure 3.7, the marginal effects of IKRFs Rajaii program have concentrated on the expenditure levels the middle three quintiles, despite its mission to help the lower quintiles. Also, the effect had been weaker before 1998. It is possible that the programs unconditional benefits and possibly its general equilibrium consequences may have made it beneficial mainly to the middle of the distribution.

Figure 3.8 indicates that SWO coverage has had significant positive effects on most of the population. The effect had been quite even across the entire distribution before 1988. But, it became somewhat smaller and lost its significance for the bottom and top deciles after 1988. The result is particularly notable because SWO is a relatively small program. But, its diverse mission seems to entail benefits for broad segments of the population. The change after 1998 seems to be due to the reorientation of SWO to support modern NGOs that mostly operated in major urban areas (Esfahani, 2005).

Turning to the role of SSO activities, Figure 3.9 shows that after 1998, the mandatory and especially the optional SSO schemes have beneficial effects for a wide range of the population, especially the middle class. These programs do not seem to have been reaching the lowest decile of the distribution effectively. Furthermore, the optional insurance program does not appear to make much of a difference for the top decile. SSOs unemployment insurance, on the other hand, seems to have has positive effects for the bottom 60 percent of households, particularly the lowest three deciles.

The estimates of SSO variables for the pre-1998 period appear rather puzzling. In particular, the mandatory insurance program shows negative effects on the real expenditures of all households. This could be because of the data problems for 1993-1995 mentioned above in the discussion of data. It might also reflect the consequences the economic crisis of 1994-1995, which caused a sharp and unexpected rise in inflation, with little adjustment in the benefits paid out by SSO. As a result, those who had expected to depend on SSOs mandatory program found themselves worse off. For the optional program, which began to expand in the 1990s, the initial benefits seem to have gone to the top half of the distribution. This may be due to the fact that in the earlier years, higher income groups had been in a position to take advantage of the program. The unemployment insurance program was also limited before 1998 and, naturally, its effect was small, though still positive for the poor. The effects grew stronger as these programs expanded after 1998.

The above results capture effects of public programs through their province-level variations. The only set of variables that provides me with a glimpse of the role of economy-wide factors is the year fixed effects, depicted in Figure 3.10. The pattern of these effects is indeed informative. The first four graphs in this figure capture the impact of the economic crisis of 1994-1995. They show that the episode drove down everyones real expenditure more or less by the same percentage in 1994. However, soon its effects became strongly regressive as the expenditures of bottom 70 percent declined further in 1995, while the top decline experienced recovery. In 1996, the effect of the economy-wide factors on the bottom deciles started to rise in 1997 it was much higher than the effects of the same factors for the middle quintiles. In 1998, the effect of the economy-wide factors had more or less returned to their 1993 levels. In the following years, this effect started to drift down, especially for the top deciles, though always remaining statistically insignificant.

I now turn to the effects of household characteristics on the pattern of household expenditure in Iran. The marginal effects of being urban and female-headed household are presented in Figure 3.11. Note that as expected, urban households spend a lot more than the rural ones. Part of this is likely to be due to differences in urban and rural price indices. However, that effect alone cannot explain the large gap in expenditure and the downward slope of the effect as quantiles rise. The latter pattern is consistent with the relative mobility of upper income rural households compared to their lower income counterparts. The right-hand side graph in Figure 3.11 reveals that when the household is headed by a woman rather than a man, expenditure is significantly lower, especially for the lower quantiles: by more than 35 lower for the bottom decile and about 23 percent for upper decile. Disadvantages of being a female head of household seem to be less pronounced when they have other characteristics, such as innate abilities or other assets, that enable them to enjoy higher expenditures compared to their male counterparts.

Figure 3.12 presents the results for household size and education variables. Household size clearly matters a great deal for real expenditure. The effect turns out to be substantially larger for the lower expenditure quantiles, possibly because they have relatively smaller fixed costs and the presence of an additional person in the household raises expenditure by a larger percentage. Education of non-student adults also raises household expenditure, as expected. Interestingly, the effect of education is lower among upper quantiles. A plausible explanation for this finding is that in the upper ranges of the distribution, households possess larger amounts of other assets, reducing the marginal effect of education on their incomes and expenditures.

The estimated effects of age of head of household are shown in Figure 3.13. Household expenditure has an inverted-U relationship with age that is much more pronounced for lower quantiles than for the upper ones. Higher income household heads seem to be able to smooth their consumption and possibly their incomes over their life cycle. The peak of the overall age effect is also rising with the expenditure quantile, ranging from about age 49 for the lowest quantiles to about 54.6 for the top decline.

Finally, Figure 3.14 presents the effects of the number of children, teenagers, and elderly in the household. The results show that children are associated with lower household expenditure, while teenagers and elderly tend to raise it. The latter effects both turn out to be larger for the upper quantiles. As pointed above, the pattern for the teenagers from high income households may be due to the higher expenditures (e.g., for private education). For the number of children, the effect has a much smaller magnitude for the rich, possibly because of the fixed costs mentioned above, or due to relatively more resources that richer household can afford to allocate to their children.

3.8 Assessing the Model and Decomposing the Trends in Household Expenditure Distribution

In this section, I first assess how well the fitted model represents the actual trends in household expenditure distribution. I then analyze the role that various factors have played in the past trends in the distribution. This is important because the effects that I have measured may have positive or negative consequences for each quantile depending on the direction and size of changes in the determinants of expenditure. For example, while the regression results show that the effect of SWO on a wide range of expenditures has been positive, the consequences could be nil or negative due to the reduction in the activities of the organization. To make the assessment task manageable and make the analysis more concrete, I focus on the 1998-2005 period when the reformist government of President Khatami stabilized the economy while changing the structure of social protection programs.

To identifying the sources of shifts in expenditure distribution, I employ the Machado-Mata technique, which is an extension of Oaxaca decomposition to the case of distributional shifts. This technique requires simulating a sample from the estimated conditional distribution and then performing experiments with it by changing the distribution of various determinants. I start with the distribution of household characteristics and conditions in 1998 and calculate their predicted expenditures using the quantile regression results for every five percentile (0.05, 0.10, , 0.95). For every household, I get 19 estimates, depending on the segment of the distribution in which they may land. I then draw a random value from the uniform distribution between 0 and 1 to select a quantile for that household. I do the same for the 2005 household sample. Finally, I use the selected samples to analyze the simulated distributions. Resampling changes the outcome somewhat, but the broad characteristics of the simulated sample remain remarkably stable.

Figure 3.15 compares the actual shift in the distribution of household expenditures between 1998 and 2005 with the one based on the simulated samples for those two years. The predicted values are remarkably close to the actual shifts, giving me confidence that the model is a good estimate of the underlying situation. (Note that the match between the predicted shift with the actual one is much more stringent than getting a good fit for the levels each year.) There are of course gaps between the two curves in the middle and upper quantiles, but the overall shape of the shift is captured by the estimated coefficients and variable changes. Examining the factors that cause the simulated distributional shift to slope downward toward in the upper deciles and make it deviate from the actual distribution led me to notice that the it is essentially driven by the shift in the year fixed effect, shown in Figure 3.16. I cannot be sure what factors caused this deviation, but subtracting the shift in the year fixed effect from the overall shift produces a curve (benchmark shift) that follows the pattern of the actual distribution more closely. This means that the variables included in the model seem to be the main drivers of the shift in the actual distribution.

To decompose the benchmark shift, I The quantile regression method and the household expenditure surveys that I have employed to assess the role of policy and household characteristics in distributional shifts in Iran have yielded novel and useful results. I find that economic growth in Iran has been unequalizing, but province-level government expenditures, a key agency providing social safety net (IKRF), and expansion of education have counteracted with that effect and, on the whole, have helped lower inequality in the 1990s and 2000s. This finding is important particularly because Iran has experimented with new forms of institutions such as IKRF to provide social protection. The success of these institutions makes it worthwhile to examine them more closely and to derive general lessons from them that can be useful in Iran and elsewhere. There is, of course, much more to be done to fully understand the determinants of distributional shifts. Some important factors have been captured in cross-sectional and time fixed effects. Much more data with longer series is needed to discern those factors. Furthermore, some of the variables considered here are connected with each other and with other factors. Determining those connections could lead to better measurement of direct and indirect effects and to the identification of more fundamental factors that drive income distribution. Also, more work and more powerful statistical packages are required to deal with endogeneity and simultaneity issues. Nevertheless, the approach is very useful because it opens up possibilities for examining many other distributional issues. For example, with appropriate data, one may be able to assess the impact of infrastructure and other large projects across household. Other important issues in the case of Iran are: how and why those in the middle of the distribution were left out between the early 1990s and mid-2000s, what roles they played in the rise of populism and reactions to it after the mid-2000s? start with the 1998 simulated distribution and raise the per capita expenditure variable to its 2005 level in each province. Figure 3.17 shows that this causes a large shift in the 1998 distribution, with a significant upward tilt. Comparing this curve with the benchmark shift shows that growth explains the bulk of the shift. However, growth is associated with considerably greater inequality, contrary to the actual situation that has been far more favorable for the poor. To understand how this gap has been filled, I begin with two exercises. First, I calculate the shift in the simulated 1998 distribution if all policy variables are set equal to their 2005 levels, keeping the distribution of household characteristics constant. Second, I measure the shift in the distribution when household characteristics are set equal to the 2005 sample, but policies and per capita expenditure is kept the same as in 1998. The results of these two exercises, shown in Figure 3.17, suggest that the two sets of factors have had broadly similar roles in the distributional shift. However, household characteristics have been more uplifting for the bottom deciles and policy variables have helped the top decile somewhat more.

The next question is which policies account for the overall role that policies have played during 1998-2005. To address this question, I mapped the shift from the simulated 1998 distribution when each policy variable was updated to its 2005 level. Figures 3.18-3.20 present the results. It is clear from Figure 3.18 that a large part of the expenditure and distributional consequences of policies during the period can be attributed to province-level government expenditures. The SWO+NGO combination, which had been largely stagnant after 1998 had in fact had a small negative effect for the bottom 70 percent, while slightly helping the top quarter of the households! Figure 3.19 further reveals that the mandatory and optional schemes of the SSO had been beneficial to the population, but with opposite distributional consequences. The benefits of the mandatory program had been rising with quantiles, while the opposite is true for the optional program. This makes sense because the mandatory program tends to focus on the employees of large enterprises, especially the public and quasi-public ones, who happen to be among the better off segments of the population. The optional plan, on the other hand, has been creating options for household from other social strata and, consequently, has benefitted them. Figure 3.19 further shows that the unemployment insurances scheme of SSO has had virtually no effect on the expenditure distribution. This could be because the economy was rapidly expanding during 1998-2005 and few employed workers were losing their jobs to take advantage of the scheme. Of course, there were many unemployed young people in that period, but they had not found jobs to become eligible for the unemployment insurance program.

The distributional shift attributable to IKRF spending, mapped in Figure 3.20, follows the effect I have observed in the previous section: It has had a positive impact on the bottom half of the population, with the effect rising and becoming quite tangible for the lower quantiles. The overall impact of the Rajaii program, on the other hand, has been negative, except for the top and bottom deciles. The reason for this surprising finding is that the coverage and the pensions paid by the program were declining during 1998-2005, as the government was taking away resources from IKRF. This factor did not lead to negative outcome for the other IKRF programs because it could use its own revenues for those purposes and had an incentive to support the poor and elicit their loyalty to the system.

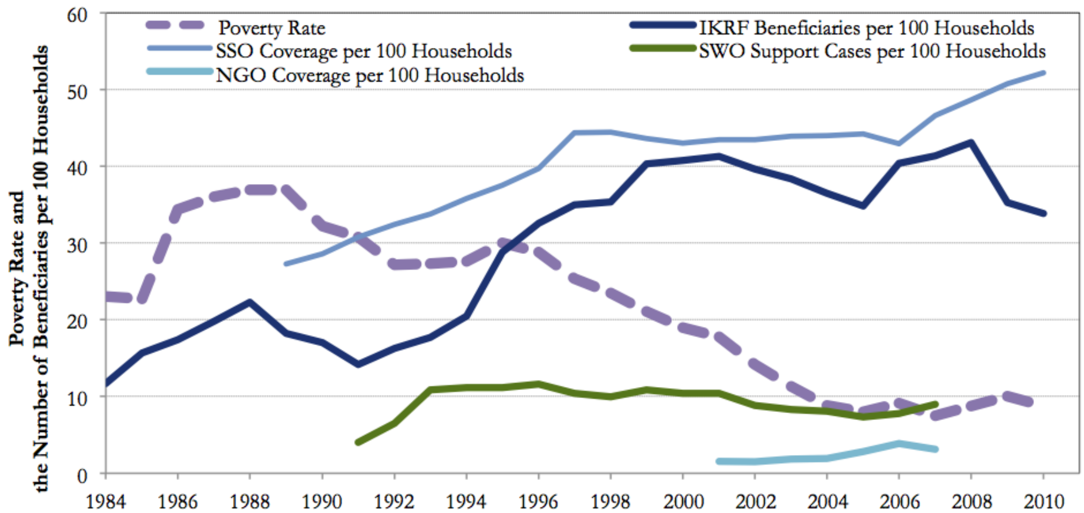
For decomposing the effects of household characteristics, I start with the 1998 joint distribution of all household characteristics and then shift the each percentile of the distribution of each characteristic separately to make it reach its 2005 level. This yields a new distribution for each variable that can be used to measure its marginal effect. The procedure assumes that one characteristic, say education, can be changed independently of other characteristics, while in reality such a neat separation may not hold. However, the exercise is still useful because one can combine the shifts in characteristics as needed to arrive at patterns that may be more realistic. In any case, for most household characteristics I found that they had not changed enough to make a difference (urbanization, age of head of household, female-headed households, and the number of teenagers and elderly in the household). The variables that have sizable impact are education, household size, and the number of children. The reduced household size has reduced household expenditure across the board, but this has been almost entirely due to the reduced number of children in the household, which has raised expenditure for each given household size. Since these two factors are closely interconnected, I shift them in tandem and report the net results in Figure 3.21. It turns out that the reduce number of children and household size jointly have reduced household expenditure with smaller effects for higher quantiles, except for the bottom 5 percent. This leaves education to explain the positive effect of household characteristics changes on expenditures and distribution. This observation is clearly born by the simulated shift shown in Figure 3.21.

3.9 Conclusion

The quantile regression method and the household expenditure surveys that I have employed to assess the role of policy and household characteristics in distributional shifts in Iran have yielded novel and useful results. I find that economic growth in Iran has been unequalizing, but province-level government expenditures, a key agency providing social safety net (IKRF), and expansion of education have counteracted with that effect and, on the whole, have helped lower inequality in the 1990s and 2000s. This finding is important particularly because Iran has experimented with new forms of institutions such as IKRF to provide social protection. The success of these institutions makes it worthwhile to examine them more closely and to derive general lessons from them that can be useful in Iran and elsewhere.

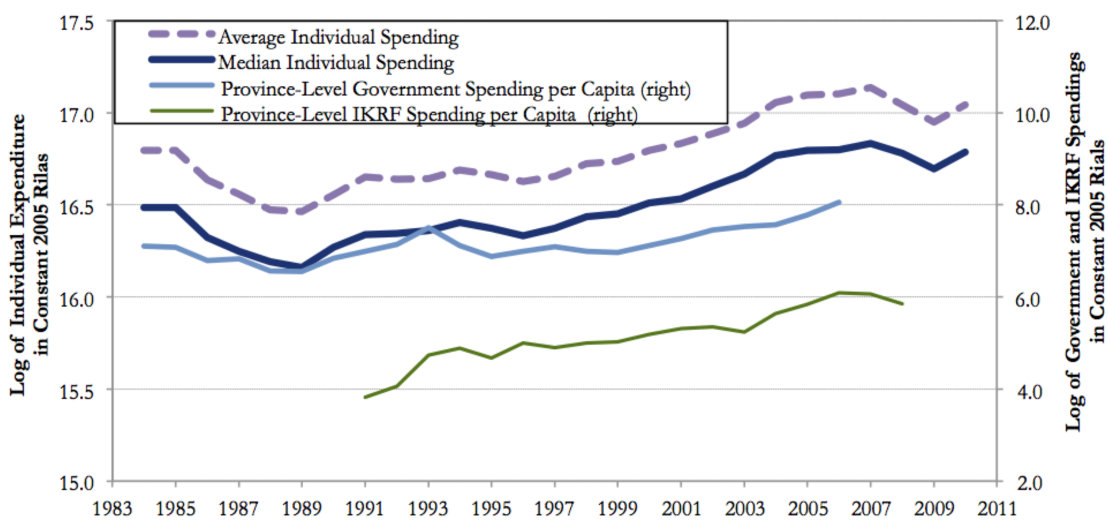
There is, of course, much more to be done to fully understand the determinants of distributional shifts. Some important factors have been captured in cross-sectional and time fixed effects. Much more data with longer series is needed to discern those factors. Furthermore, some of the variables considered here are connected with each other and with other factors. Determining those connections could lead to better measurement of direct and indirect effects and to the identification of more fundamental factors that drive income distribution. Also, more work and more powerful statistical packages are required to deal with endogeneity and simultaneity issues. Nevertheless, the approach is very useful because it opens up possibilities for examining many other distributional issues. For example, with appropriate data, one may be able to assess the impact of infrastructure and other large projects across household. Other important issues in the case of Iran are: how and why those in the middle of the distribution were left out between the early 1990s and mid-2000s, what roles they played in the rise of populism and reactions to it after the mid-2000s?

Figure 3.1: Poverty Rate and the Coverage of the Main Social Protection Programs in Iran



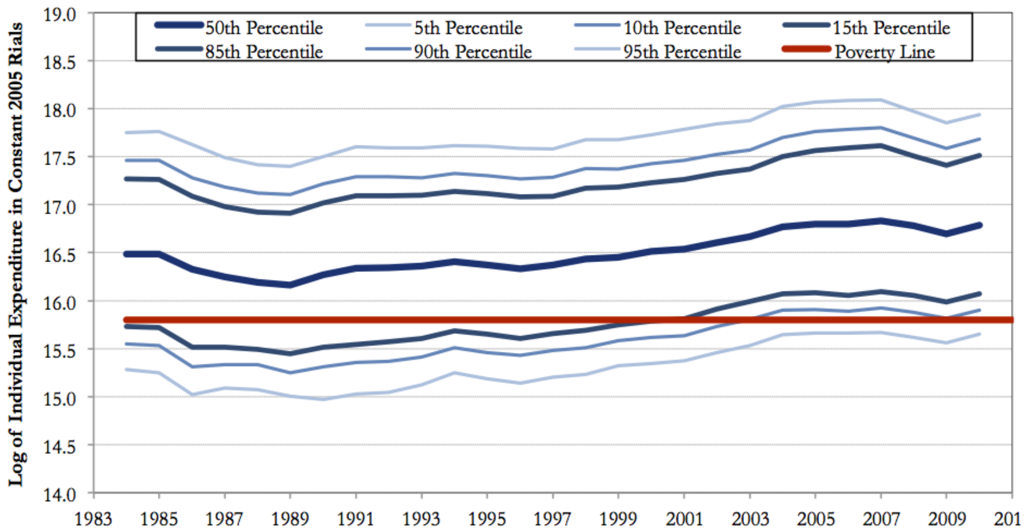
Source: Calculated based on data from IKRF Statistical Reports, the Statistical Yearbook of Iran, and the Household Expenditure and Income Survey Dataset.

Figure 3.2: Mean and Median Individual Expenditure and per Capita Government and IKRF Spending in Iran



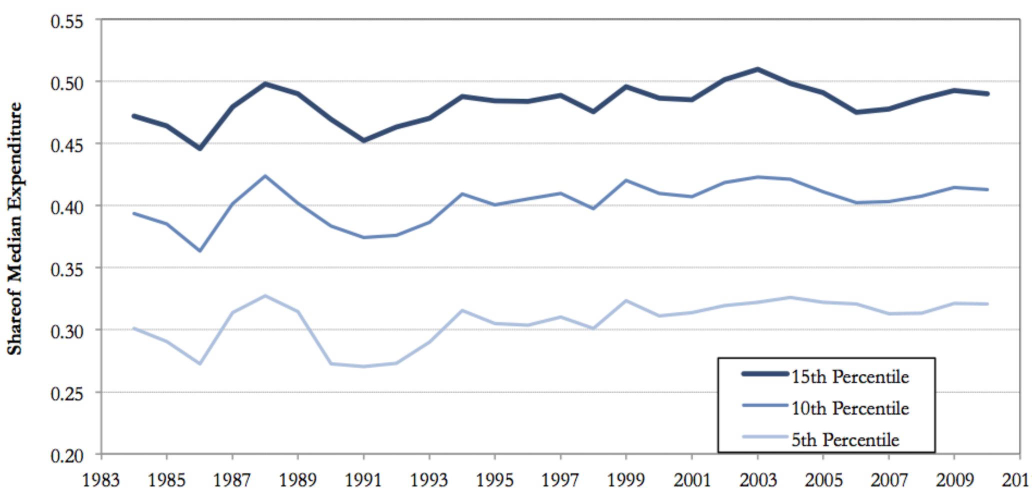
Source: Calculated based on data from IKRF Statistical Reports, the Statistical Yearbook of Iran, and the Household Expenditure and Income Survey Dataset.

Figure 3.3: Evolution of Quantiles of Individual Expenditure Distribution in Iran



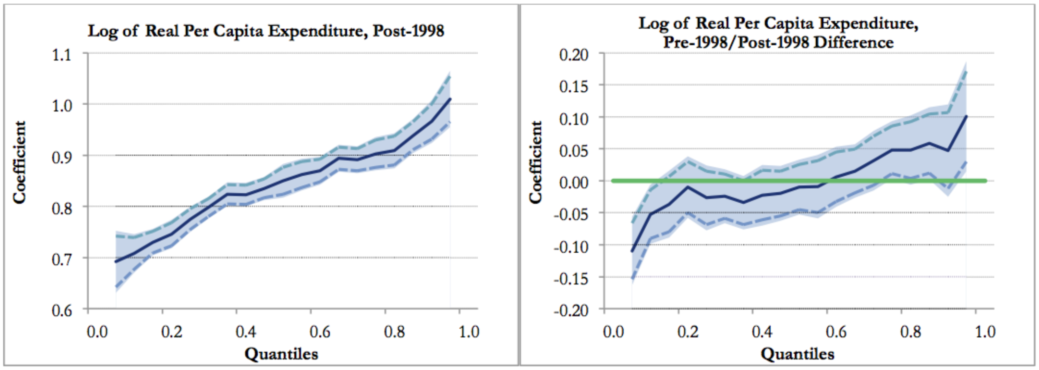
Source: Calculated based the Household Expenditure and Income Survey Dataset.

Figure 3.4: The Bottom Quantiles of Individual Expenditure Distribution Relative to the Median



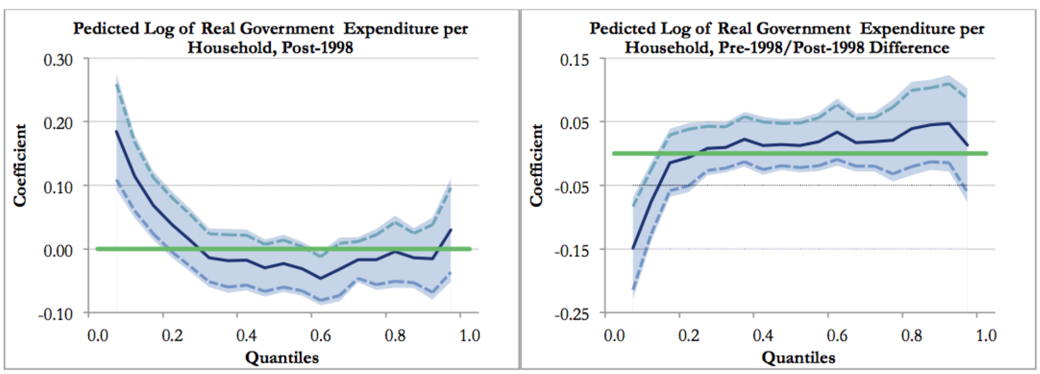
Source: Calculated based the Household Expenditure and Income Survey Dataset.

Figure 3.5: Quantile Regression Results:
Estimated Coefficients of Per Capita Expenditure



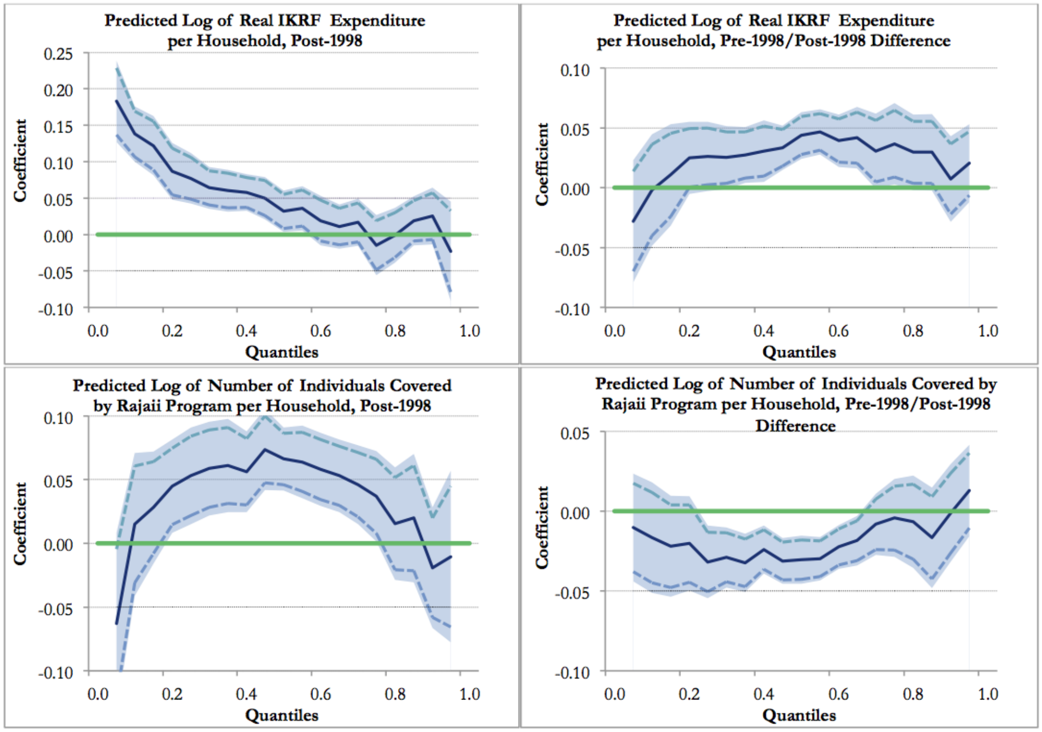
Note: Shaded areas are the 95% confidence intervals based on bootstrapped standard errors. Dashed lines show the 90% confidence interval.

Figure 3.6: Quantile Regression Results:
Estimated Coefficients of Government Spending per Household



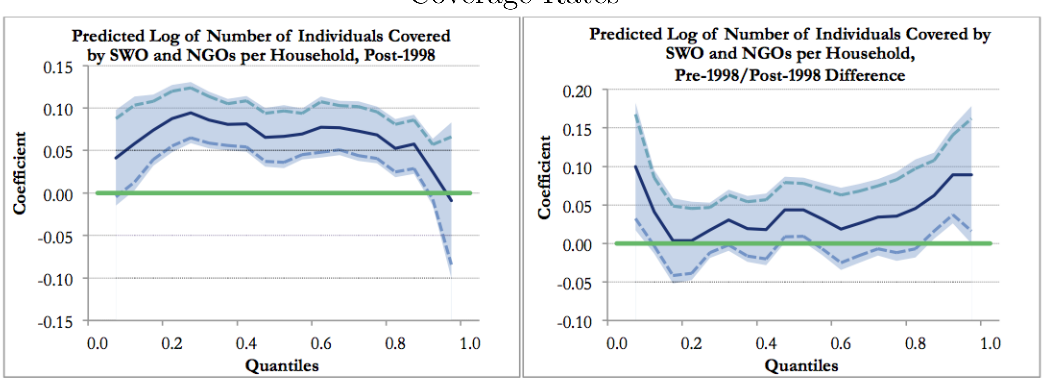
Note: Shaded areas are the 95% confidence intervals based on bootstrapped standard errors. Dashed lines show the 90% confidence interval.

Figure 3.7: Quantile Regression Results:
Estimated Coefficients of the IKRF Activity Measures



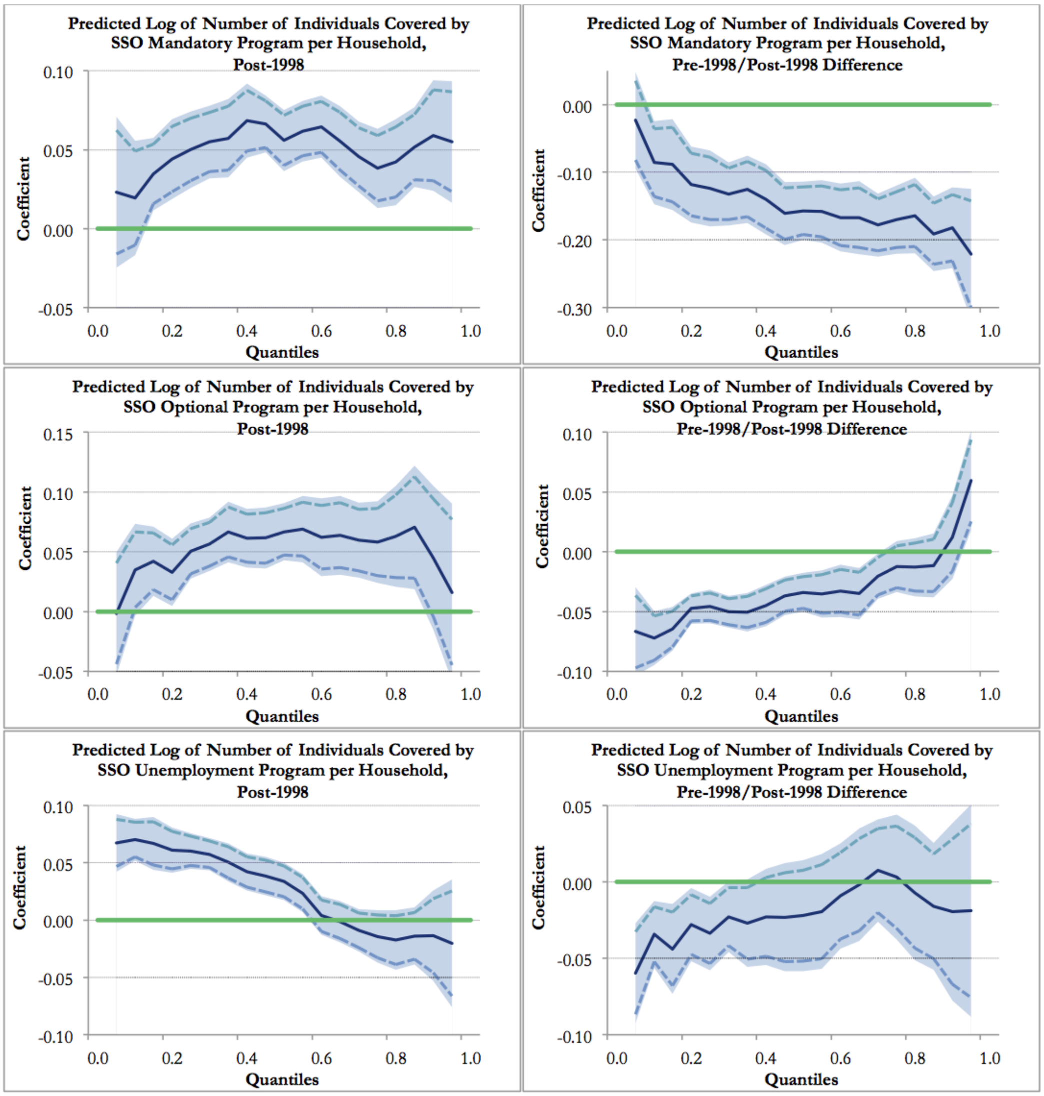
Note: Shaded areas are the 95% confidence intervals based on bootstrapped standard errors. Dashed lines show the 90% confidence interval.

Figure 3.8: Quantile Regression Results:
Estimated Coefficients of the Social Welfare Organization and NGO Coverage Rates



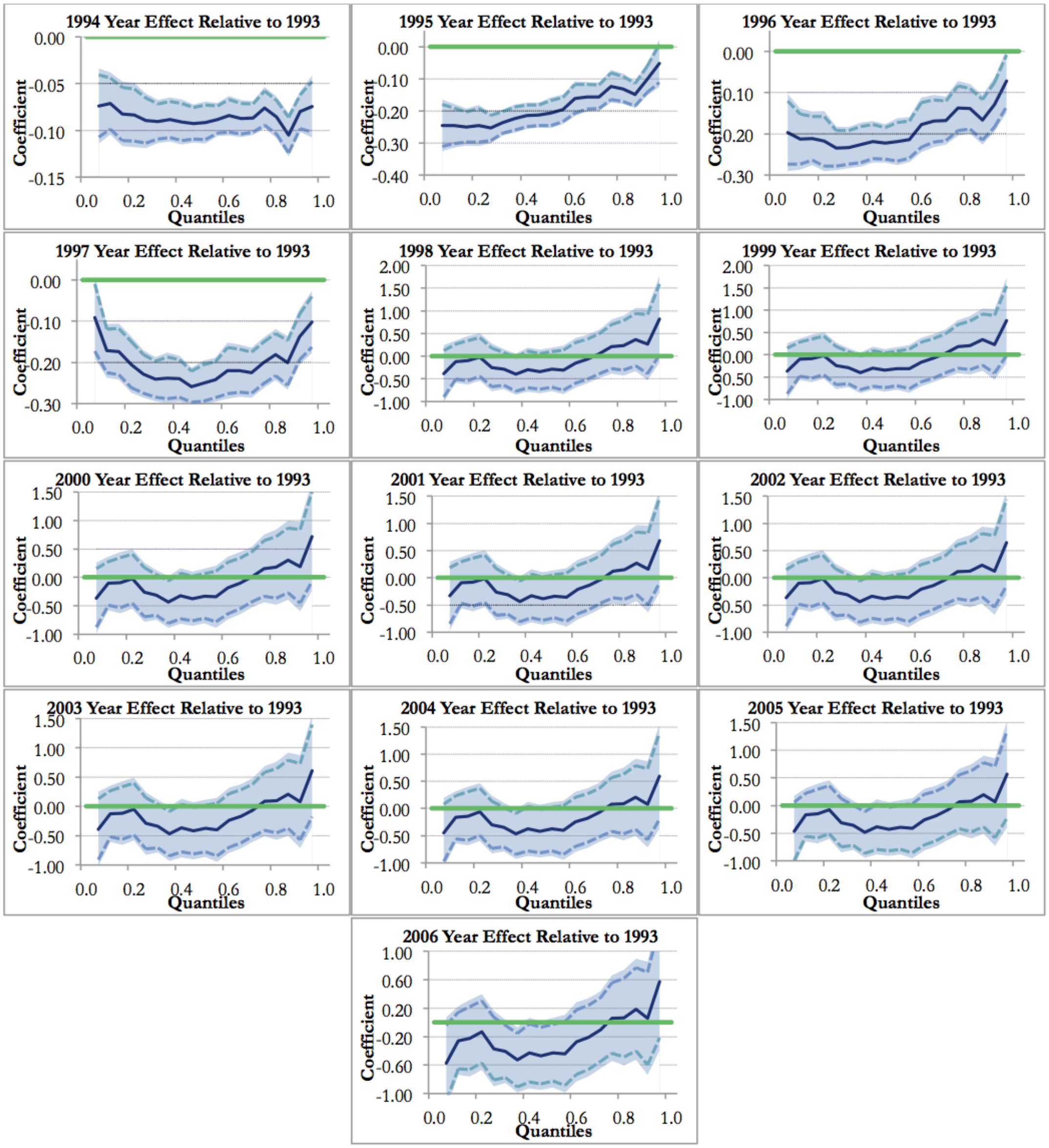
Note: Shaded areas are the 95% confidence intervals based on bootstrapped standard errors. Dashed lines show the 90% confidence interval.

Figure 3.9: Quantile Regression Results:
Estimated Coefficients of the Social Security Organization Coverage Measures



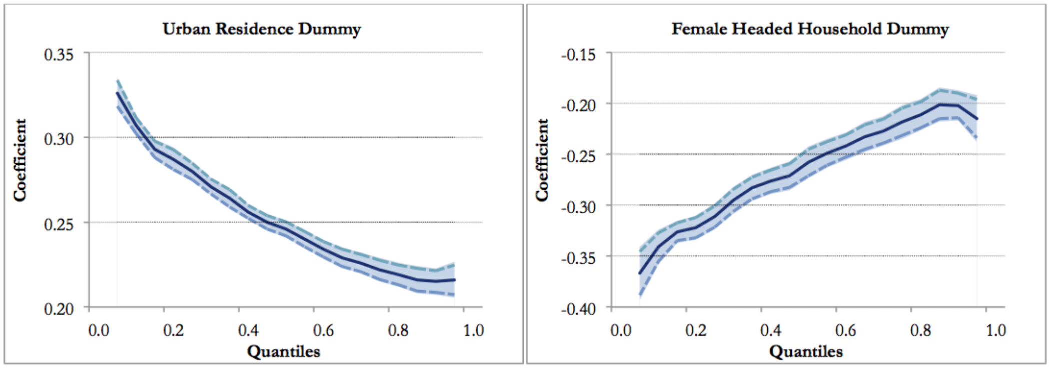
Note: Shaded areas are the 95% confidence intervals based on bootstrapped standard errors. Dashed lines show the 90% confidence interval.

Figure 3.10: Quantile Regression Results:
Estimated Coefficients of Year Effect Relative to 1993



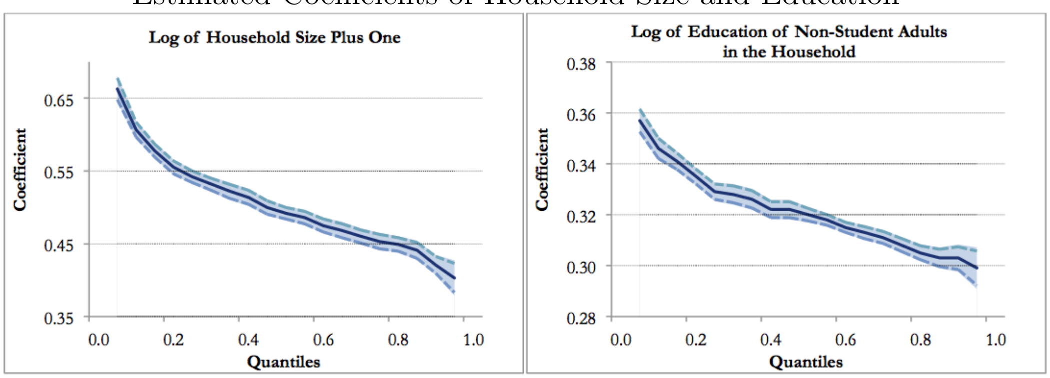
Note: Shaded areas are the 95% confidence intervals based on bootstrapped standard errors. Dashed lines show the 90% confidence interval.

Figure 3.11: Quantile Regression Results:
Estimated Coefficients of Residence Location and Gender of Head of Household



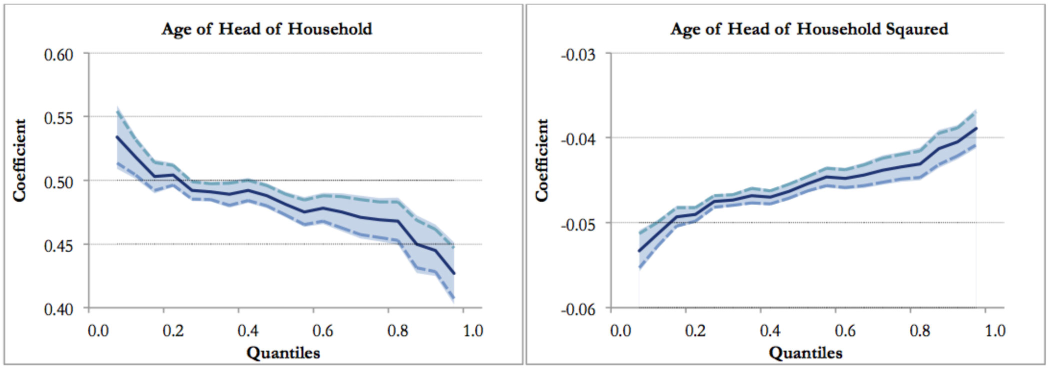
Note: Shaded areas are the 95% confidence intervals based on bootstrapped standard errors. Dashed lines show the 90% confidence interval.

Figure 3.12: Quantile Regression Results:
Estimated Coefficients of Household Size and Education



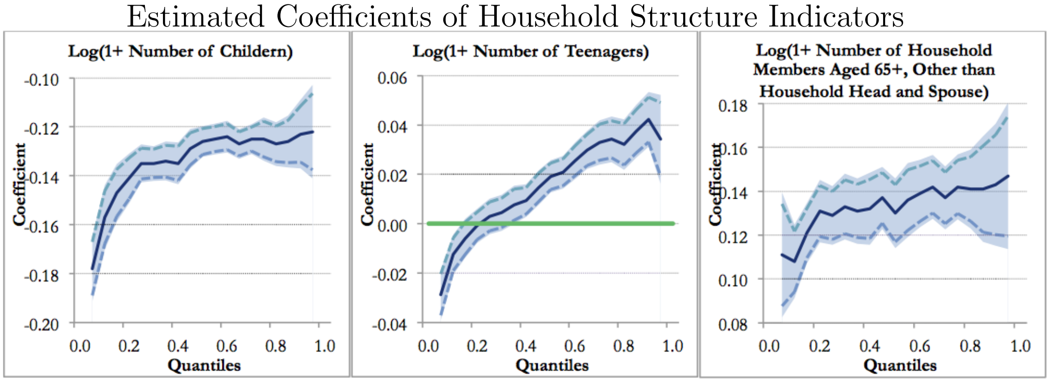
Note: Shaded areas are the 95% confidence intervals based on bootstrapped standard errors. Dashed lines show the 90% confidence interval.

Figure 3.13: Quantile Regression Results:
Estimated Coefficients of the Age of Head of Household



Note: Shaded areas are the 95% confidence intervals based on bootstrapped standard errors. Dashed lines show the 90% confidence interval.

Figure 3.14: Quantile Regression Results:
Estimated Coefficients of Household Structure Indicators



Note: Shaded areas are the 95% confidence intervals based on bootstrapped standard errors. Dashed lines show the 90% confidence interval.

Figure 3.15: Predicted vs. Actual Change in Quantiles of Household Real Expenditure Between 1998 and 2005

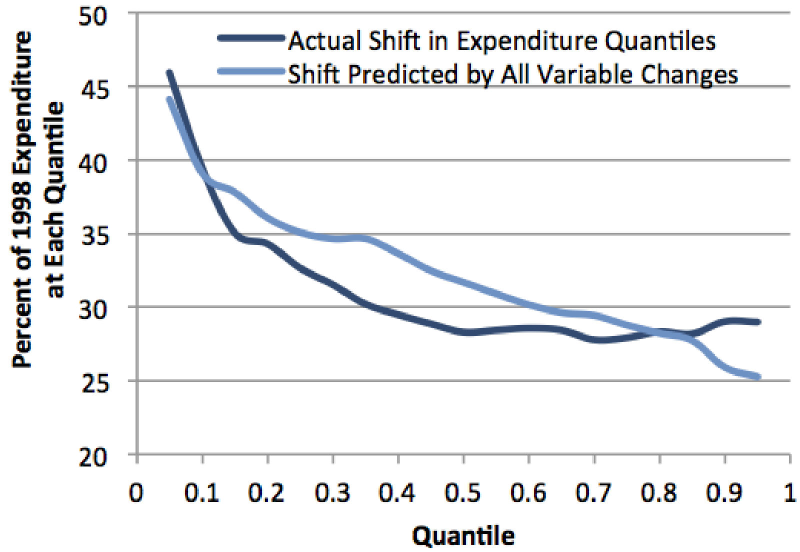


Figure 3.16: Year Effect vs. All Other Factor Effects on Quantiles of Household Real Expenditure Between 1998 and 2005

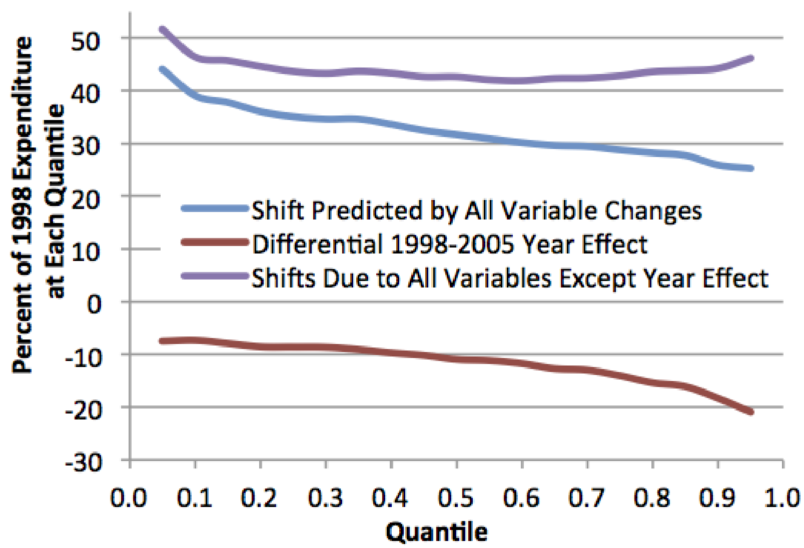


Figure 3.17: The Effects of Growth vs. Changes in Policy and Household Characteristics on Quantiles of Household Real Expenditure Between 1998 and 2005

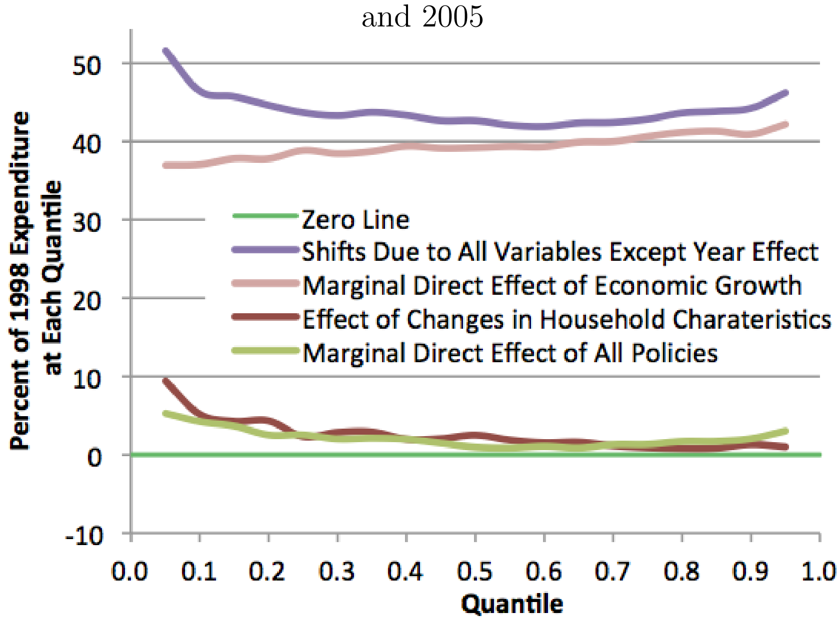


Figure 3.18: The Effects of Province-Level Government Spending and SWO/NGO Activity on Quantiles of Household Real Expenditure Between 1998 and 2005

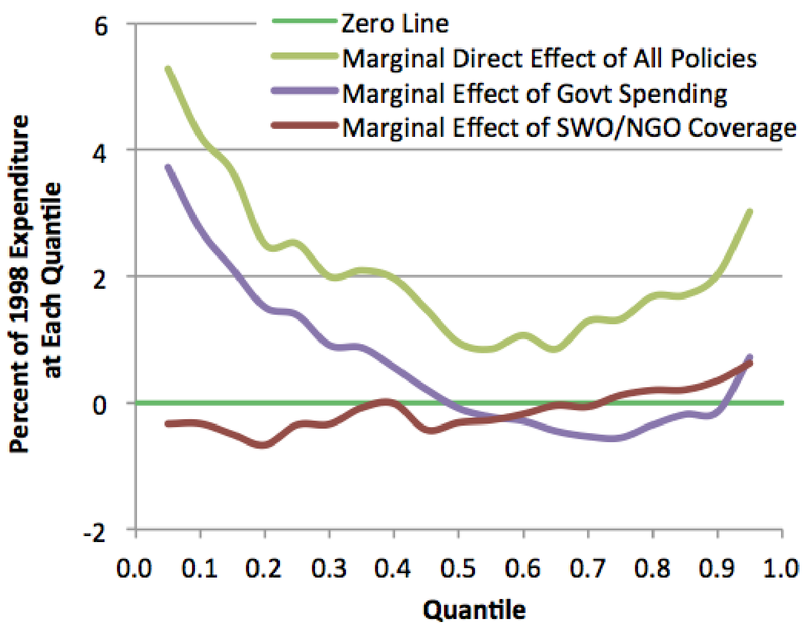


Figure 3.19: The Effects of SSO Activities on Quantiles of Household Real Expenditure Between 1998 and 2005

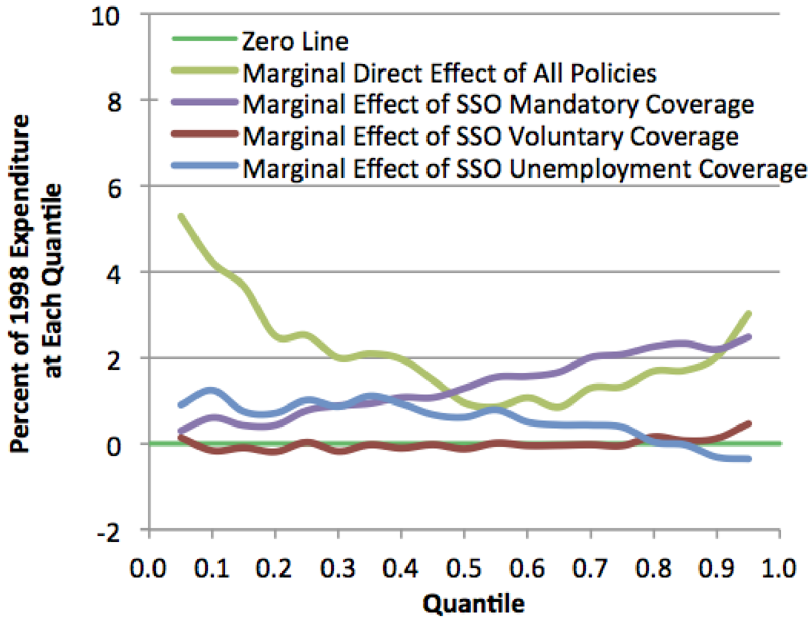


Figure 3.20: The Effects of IKRF Activities on Quantiles of Household Real Expenditure Between 1998 and 2005

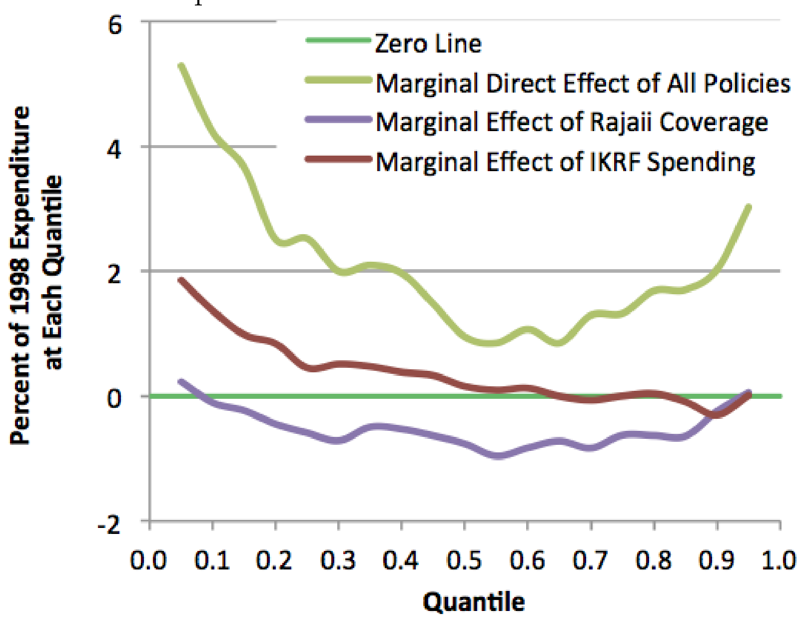


Figure 3.21: The Effects of Household Size and Education on Household Real Expenditure Between 1998 and 2005

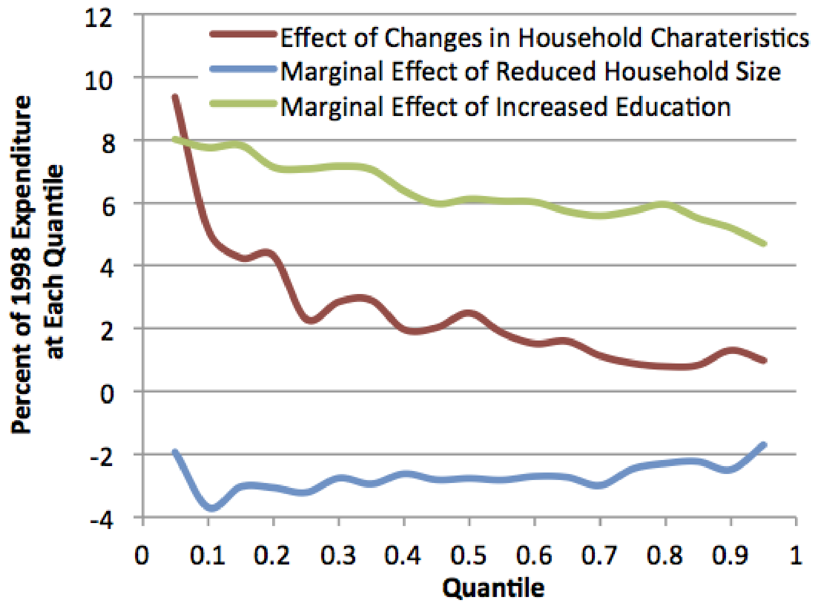


Table 3.1: Summary Statistics of the Variables Used in the Regressions

	Mean	Std. Dev.	Min-imum	Maxi-imum
Province-Level Variables:				
Log of Real Per Capita Expenditure in 1997 Rials	11.02	0.31	10.28	11.86
Log of Real Government Expenditure per Household in 1000s of 1997 Rials	-3.03	0.45	-4.28	-1.56
Log of Real IKRF Expenditure per Household in 1000s of 1997 Rials	-5.52	0.81	-7.8	-2.6
Log of Number of Individuals Covered by Rajaii Program per Household	-2.27	0.85	-5.19	-0.53
Log of Number of Individuals Covered by SWO per Household	-2.27	0.58	-5.71	-0.87
Log of Number of Individuals Covered by SSO Mandatory Program per Household	-1.23	0.47	-2.65	2.23
Log of Number of Individuals Covered by SSO Optional Program per Household	-3.4	0.93	-8.35	-2.09
Log of Number of Individuals Covered by SSO Unemployment Program per Household	-5.41	0.78	-9.79	-3.75
Number of Households per Province	1041	822	35	5372
Household-Level Variables:				
Log of Real Household Expenditure in 1997 Rials	12.34	0.27	11.67	13.04
Log of 1 + Household Size	1.47	0.54	0	3.69
Log of Education of Non-Student Adults in Household	1.38	0.88	0	3.09
Age of Head of Household	4.74	1.54	0.8	9.9
Female Headed Household Dummy	0.09	0.29	0	1
Log of 1 + Number of Young Child in Household	0.73	0.44	0	1
Log of 1 + Number of Teenager in Household	0.42	0.49	0	1
Log of 1 + Number of Household Members Aged 65+	0.09	0.22	0	1
Urban Residence Dummy	0.49	0.5	0	1

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